THE UNIVERSITY OF ALBERTA

HARVEST SIMULATION TO AID DECISION MAKING

by

WILLIAM DOUGLAS CAMPBELL

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF AGRICULTURAL ENGINEERING

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "Harvest Simulation to Aid Decision Making" submitted by William Douglas Campbell in partial fulfilment of the requirements for the degree of Master of Science.

To

my grandfather, whose continuing desire
for knowledge provided the stimulus for and
direction of my academic career.

ABSTRACT

Weather influences many aspects of agricultural production. It directly effects many physical operations in farming and significantly increases the realm of uncertainty, making farm decision making most complex. The speed and efficiency of harvesting cereal grains is very dependent on weather conditions. Because of the great fluctuations in weather, sizing machines and selecting best methods of harvesting are very difficult tasks.

The primary objective of this investigation was to develop accurate models of presently accepted harvesting systems by incorporating the effects of weather, growing conditions and machine operation into the models. The complexity of climatic, biological and machine interactions during harvest was analyzed by using digital computer simulation models.

The process of harvesting cereal grain consists of three basic events:

a) grain maturation,

b) grain threshing, and

c) grain storage.

The function of each step is regulated by certain operating conditions, processing rates and limiting conditions. The four harvesting systems used for simulation were:

1) combining swathed grain moist,

2) combining swathed grain dry,

3) straight combining moist, and

4) straight combining dry.

To obtain simulation results for a wide range of farming situations, simulation runs were made using six various combine capacities on three

farm sizes in the Beaverlodge, Lacombe and Lethbridge areas of Alberta. Each simulation generated yearly distributions for: total harvest days, maturation days, bad harvest days, bushels lost, dry and moist bushels harvested and the cost of drying or chemical treatment of the moist grain. Determination of optimal combination of subsystems was not considered because of the large number of combinations involved and the lack of economic data relating to many harvesting operations.

The results of the simulations substantiated the logical assumptions that combine capacity and acreage effect harvest completion percentages, and that moist grain harvesting systems would be completed before dry harvesting systems. However, moist systems did not appear to be competitive unless acreages were sufficiently large to effect chances of completion or where the opportunity costs of a longer harvest period outweighted the cost of handling moist grain. Results also indicated that moist grain systems might be considered favorably where the farming operations include feeding some or all of the grain harvested. This was especially true in northern areas of the province where the harvest season is short and cold night air makes natural air chilling feasible.

A hypothetical farming situation was used to demonstrate the capability of simulation as an aid to management decisions.

ACKNOWLEDGEMENT

I would like to express sincere thanks to everyone involved in the preparation of this thesis. I am particularly indebted to Professor J.B. McQuitty for his advice and guidance with this research project.

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1. INTRODUCTION AND OBJECTIVES

Weather influences many aspects of agricultural production. It directly affects many physical operations in farming and thus may restrict the time available and the efficiency of specific tasks. Weather effects are not only restricted to agriculture, but also influence the operations of other industries such as the construction and building trades. Weather variations also affect the biological environment which in turn may indirectly influence the operations of related industries. Such is the case in agriculture where weather significantly increases the realm of uncertainty and makes decision making very complex.

Of the various farming operations, harvesting might be considered the last link in the production chain from which revenues are realized. The speed and efficiency of harvesting is very dependent on weather conditions. Because of the great fluctuations in weather, sizing machines and selecting best methods of harvesting are very difficult tasks.

The objectives of this investigation are:

(1) to develop accurate models of presently accepted cereal grain harvesting systems;

(2) to incorporate weather influences in these models;

(3) to perform a comparative evaluation of these harvesting systems using specific criteria;

(4) to suggest a possible "best alternative" based on the results of the evaluation; and

(5) to suggest possible areas where further investigations may decrease the uncertainty of many farm decisions.

2. LITERATURE REVIEW

McCall(57) in 1926 stated that "In the readjustment of agriculture through which we are passing, it is universally recognized that the reduction of operating costs is of prime importance. Aside from increased price or increased marketing efficiency, it is obvious that lower costs will at least partially remedy the discrepancy which exists between income and expense in crop production".

2.1 History of the Combine-Harvester and Windrower

One of the major areas of crop production where great progress has been made is in harvesting and in particular the combined harvester-thresher. MacGregor(52) outlined the early history of such machines. The U.S. Patent Office lists a patent covering a combined harvester-thresher as early as 1828. These pioneers were attempting to introduce not only a new harvesting machine but a new harvesting method. It was not until the 1870's in California that interest in these machines was renewed. However, acceptance of the 'combine'* was slow until World War I, but following their introduction into Kansas, its use spread rapidly into all areas of North America where cereal crops were grown (5, 6, 26, 36, 58, 59, 80).

In the early years of combine use, there was much discussion about the advantages and disadvantages of such a machine (6, 26, 28, 31, 39, 52, 57). The greatest advantages cited were speed and low cost per acre. The machine's unsatisfactory handling of unevenly ripened fields, green weeds, and damp grain limited its widespread acceptance.

* Over years of usage, the term 'combine' has replaced the original description of 'combined harvester-thresher'.

Later developments of the combine were primarily concerned with increasing its efficiency, durability and flexibility. These factors, accompanied by better farming practices and grain varieties, have lead to the universal acceptance of the combine as the most satisfactory means of harvesting cereal crops.

The development of the windrower was coincidental with the advent of the combine(55). Many authors reported (33, 36, 55, 56,73) that the windrower provided the answer to problems of green weeds, insects, rain, early frost and lack of uniformity of grain maturity that hampered users of the combine. Since the tendency of the farmer to wait until uniformity of ripening was achieved decreased the advantages of the windrower, straight combining gradually replaced the need for windrowing as a necessary step in the harvest procedure. By the 1930's, windrowing was almost forgotten(21).

Severe infestations of the wheat stem sawfly, Trachlus tabidus, later posed a threat to the practice of straight combining. An investigation at Swift Current Research Station in 1943 (21) revealed that the windrower could be used to avoid damage by this insect by cutting the grain slightly green and have conditioning occur in the windrow. As a result of this report, windrowing became an accepted practice. In spite of the fact that sawfly-resistant spring wheat varieties have been developed, straight combining has not become re-established.

2.2 Grain Storage

The prime function of grain storage facilities is to maintain the grain in a suitable condition for a period of time. The length of the storage period involved on the farm will vary widely depending upon needs and circumstances. To achieve safe storage, grain must be protected

from the detrimental action of micro-organisms and moulds. The growth of harmful organisms (insect, mites, moulds, and bacteria) that attack storaged grain may be reduced or inhibited by controlling the factors essential to their development, that is, by controlling the available moisture, oxygen and temperature in the grain (45) or by treating the grain with organic acids.

2.2.1 Moisture

Growth of harmful organisms can be prevented by reducing the moisture content of the grain. A figure of 13 - 14% is generally regarded as suitable for safe bulk storage (10)*. Most grain storage systems in the Prairie Provinces consist of dry grain storage facilities.

2.2.2 Temperature

Insect growth is retarded at temperatures less than 60°F. To control moulds, bacteria, and mites, temperatures must be lower and depend upon the moisture content of the grain. For moisture contents below 20 - 22%, chilling temperatures of about 40°F are necessary. At higher moisture levels, temperatures near freezing are needed for control (45). Chilling of moist grain by refrigeration to prevent spoilage of damp grain is a relatively common practice in the United Kingdom (12,64).

2.2.3 Oxygen

Growth of harmful organisms in stored grain may be controlled by exclusion of oxygen (15,44). Airtight storage systems have been developed to

* Moisture content values presented in this thesis are stated on a wet basis.

make use of this principle. Grain stored by this method undergoes partial fermentation and is consequently only suitable for livestock feed. There are several storage systems of this type available in the Prairie Provinces and are used by some cattle feeding operations.

2.2.4 Organic Acid Treatment

Recent research has shown that spraying the grain with small quantities of a liquid organic acid provides a practical, non-toxic, and economical means of preservation (41). Proprionic acid currently is rated as the most useful for this purpose. In this process, the biocidal properties of the lower fatty acids are used to sterilize the grain and eliminate the growth of micro-organisms. Treated grain may be removed from storage and ground or rolled without reducing the effectiveness of the preservation because the acid is retained by the grain. The organic acids used may also contribute to the nutritive requirements of the livestock consuming the treated grain. This acid treatment cannot be applied to seed grain or to grain destined for human consumption.

On the basis of the above mentioned principles, the agricultural industry has developed four methods of safe grain storage:

(1) dry grain storage

(2) chilled or refrigerated grain storage

(3) sealed or airtight grain storage

(4) chemically treated grain storage.

2.3 Operations Research and Systems Engineering

In an attempt to aid the farmer in his decision making processes, researchers have attempted to apply operations research and systems engineering techniques developed for business production and management

to agricultural problems.

The field of operations research has been mainly concerned with integrating a variety of research efforts which arise from the pure and applied sciences and evolving a 'whole' solution which satisfies each problem area (40). However, operations research has changed its character somewhat and has become less devoted to solving operational problems and more concerned with developing techniques to solve problems of general interest (43). The void left by this shift in emphasis has been filled by systems engineering researchers who also have been developing and applying techniques for solving operational and management problems. For the purpose of this study, both disciplines will be treated as an entity.

All applications of operations research techniques start with the presumption of a problem around which an analytical model may be developed. The characteristic model is organized more or less to simulate the decision-makers environment and described in terms applicable to the operations research technique used.

The problem and the decision-maker are part of a system. A system may be defined as "A collection of interacting diverse functional units such as biological, human, machine, information, and natural elements, integrated with the environment to achieve a common desired objective by manipulation and control of material, information, energy, and life" (14). The term 'system' emphasizes that an overall operational process is under consideration rather than a collection of pieces (27).

A systems approach to the problem is an effective method for gaining knowledge of the variables and understanding their interrelationships (79). This approach basically consists of determining

all the variables that effect the function of each unit or sub-system of the main system, then combining these parts into a model that will give an accurate description of the system in question.

Many techniques have been developed by operations researchers to aid in solving farm management problems. Most of these are mentioned by Hutton (43) in an extensive critical review of their applications. The areas of operations research most applicable to agriculture are:

(a) Mathematical programming

(b) Network analysis

(c) Simulation.

2.3.1 Mathematical Programming

Mathematical programming methods include linear, stochastic, integer, quadratic, separable, and dynamic programming. MacHardy (53), Anderson (1), and Russell (71) used mathematical programming to solve minimum cost machinery combinations. Stapleton and Barnes (75) used linear programming to optimize profit of a cotton producer by considering a balance of machinery, labor, price, yield, and harvesting penalties. Burt (11) used dynamic programming to determine optimum replacement for buildings and machinery under conditions of chance of failure or loss. Chou and Heady (13) applied integer programming for treatment of 'lumpy' supplies of inputs found in the operations of a dairy farm.

2.3.2 Network Analysis

Another type of operations research techniques that has been applied to agriculture is network analysis. Link (50) made use of the methods characteristic of 'Critical Path Method' (CPM) and 'Program Evaluation and Review Technique' (PERT) for analysing farm machinery

systems. This systematic approach of linking units of machinery and their activities in a sequential pattern or network has been used by Link (50), Von Bargen (79), Preston (68), and Hunt (42) to reveal the shortest or least cost alternative of machinery size or farming method.

Link and Bockhop (49) developed a network for farm machinery scheduling which was used by Link (48) to determine farm size for the optimum use of a given set of machines. Preston (68) developed a procedure called 'Shortest Path Network Analysis' (SPNA) similar to CPM, but in which the network is processed in reverse. He used this procedure to evaluate alternative irrigation methods.

2.3.3 Simulation Techniques

Harling (37) states that "By simulation is meant the technique of setting up a stochastic model of a real situation and then performing sampling experiments upon the model". This approach has not been refined as quickly as other operations research techniques because of the stochastic nature of the model and computer programming limitations. Simulation of games of war have been used extensively for training military personnel (81,30). Orcutt (66) suggested that simulation was the only satisfactory approach for studying dynamic systems and applied this method to some simple economic systems. MacHardy (54) and Russell (71) used a type of simulation to incorporate the probabilistic nature of weather influences into a program for sizing farm machines. Hunt (42) developed a series of mathematical equations to simulate interactions of variables in another approach to farm machinery selection. Alternative forage harvesting methods were simulated and evaluated by Van Bargen (79). Halter and Dean (35) applied simulation to a large ranch operation to evaluate present management policies under uncertainty of weather and

prices. Donaldson (25) carried out an extensive study of grain harvesting in Great Britain using simulation to assess the effect of 1000 'years' of synthetic harvesting weather on decisions of combine size and farm size.

Halter and Dean (35) state that "Simulation is a promising tool of analysis, particularly if uncertainty characterizes the decision making environment and a large number of time related interrelationships among variables exists". This optimism was also expressed by others (61, 70, 76, 82).

3. CHOOSING A MODEL

The characteristic model is organised to include the decision-makers environment and described in terms most applicable to the operation technique used.

Orcutt (66) states that "In using conventional mathematical techniques to solve a model, the objective is to determine deductively and with generality the way in which the model implicitly rates endogenous variables to initial conditions, parameters and time paths of exogenous variables". In agriculture, it is far more difficult to recognize and measure the essential variables, and, until this can be done, it will not be possible to develop mathematical models of the processes which are necessary for an effective systematic approach to agricultural problems (14). Alternatively, simulation can be used to solve a model. By simulation is meant the development of a stochastic model of a real situation and observing its reaction to changes of the variables. The design of a stochastic model involves the use of frequency or probability distributions of raw data and the best theoretical fit that can be obtained by their distributions (37).

Probability distributions describe both the lack of predictability of any given event and the general predictability of a population of events. In this way, events which occur beyond the limits of knowledge or the control of the participants may be used in the simulation model.

Sampling of these distributions is often done by Monte Carlo techniques (61). This method uses random number sequences to choose varying parameter values from their respective distributions. The simulation model uses these values to obtain a solution. New values are picked for each simulation run. By simulating a great number of combinations of

parameter values, a general predictable solution can be obtained.

The complexity of climatic, biological and machine interactions during the harvesting phase of cereal crop production may best be analyzed by using simulation techniques. The abilities of distribution functions to equate past situations and to absorb areas of limited knowledge are realized by model simulation. Simulation has an advantage over other prediction methods because of the inherent opportunity for progressive development as more information about the real system becomes available. The structuring and interpretation of the system model for simulation does not usually require advanced mathematical background. The mechanics of simulation procedures make simulation well suited for analysis of time-dependent systems. Because various parameters may be manipulated directly, simulation offers an advantage of versatility of combinations. The treatment of parameters by simulation models accounts for the variability of conditions, but the output information offers no optimal solution and serves only to test alternative solutions described by the analyst. This information may not justify the expense of programming and collection of large amounts of input data required by simulation techniques.

4. DESCRIPTION OF THE SYSTEM

The process of harvesting cereal grains consists of three basic events:

4.1 Grain Maturation

Maturation or ripening of cereal grain is indicated by the gradual yellowing of the straw and hardening of the grain kernel. These changes are the result of decreasing moisture levels in the straw and grain. The grain kernel reaches physiological maturity at a moisture content of approximately 35%. At this time, grain may be windrowed without any significant decrease in yield and bushel weight (17). The rate at which drying occurs after this stage will depend on environmental conditions. Standing grain may take from 3 - 5 days longer to decrease moisture levels to 14% than grain that has been windrowed (23).

4.2 Grain Threshing

During threshing, the grain kernels are separated from the grain plant and collected for transport to storage. The time of threshing is dependent on the maturity of the grain kernel. The efficiency with which the grain is separated from the plant depends on the moisture content of the grain kernel and the straw and the proper adjustment of the threshing and separating mechanisms of the combine. The rate at which the grain crop is harvested is limited by the physical capacity of the combine and its efficiency.

4.3 Grain Storage

If the harvested grain cannot be disposed of immediately, storage facilities must be available. There are several types of storage systems available for cereal grains depending on the condition of the grain harvested. Moist grain requires more elaborate storage systems

and/or better management to insure safe storage. If such conditions are not available the grain should be harvested in a dry condition.

There are several combinations of methods and equipment that bring these events together. These alternatives can easily be described by a simple network diagram as given in Figure 1.

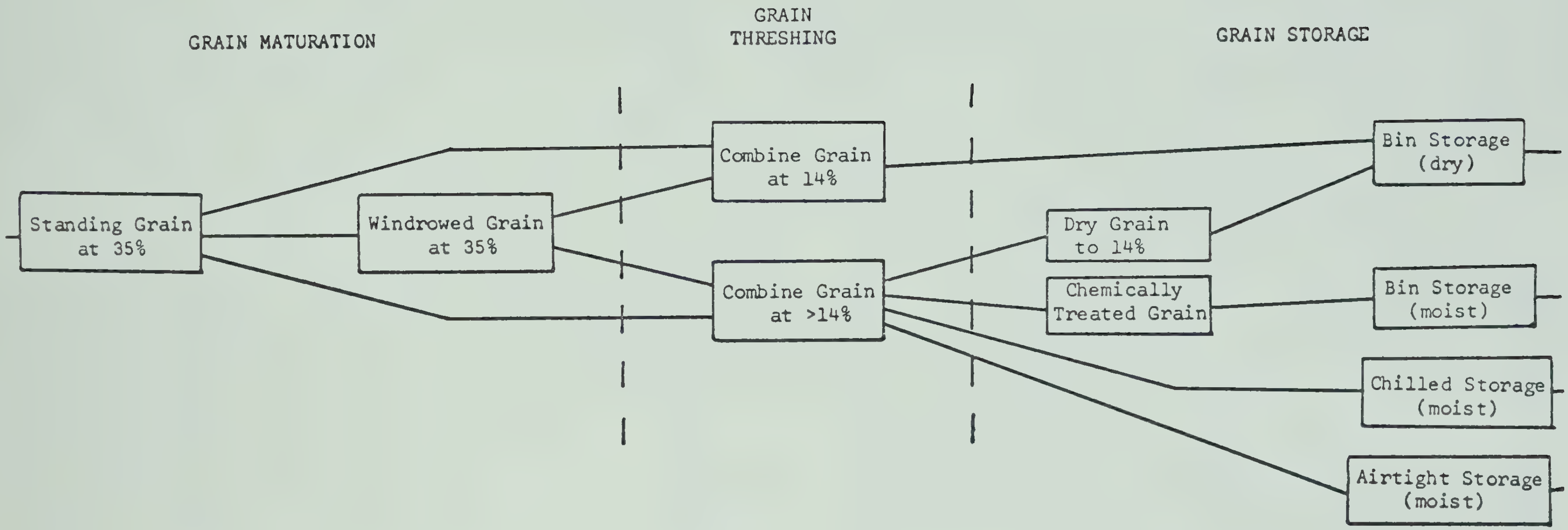

Figure 1. Network combinations of alternative harvesting systems.

5. SYSTEM ENVIRONMENT

The effectiveness of these alternative combinations depends greatly on the environmental conditions in which these systems function.

Geographical location and day-to-day variations in the weather affect the quality and duration of the growing season, resulting in variations of grain maturity and commencement of the harvesting operations. Weather conditions during the harvest period affect the speed at which harvesting can be completed. Further, the harvest season will be terminated by continuous unsatisfactory harvesting weather.

Conditions of the market, lack of capital, personal preference and risk preference can influence the acceptability of each alternative harvesting method. Seed and milling grains require higher quality standards than feed grains.

The ability of the farm operator, the size of the farm and its machine capacity will determine which harvesting methods can be completed in the time allowed by the weather conditions.

6. INTRODUCTION OF THE SYSTEM MODELS

The previously illustrated network diagram can be separated into four alternative systems. These four networks are initiated at similar grain moisture conditions and terminate when the grain is in storage. The starting point of a network is the earliest stage of maturity at which cereal grain can be windrowed without loss of yield or bushel weight. If maturity is measured by kernel moisture content, this point occurs at 35% for wheat and oats and 40% for barley (17,18,19). A moisture level of 35% has been chosen for the networks used in this study.

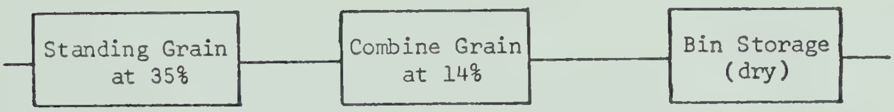

Figure 2. Straight combine sequence (dry).

Figure 3. Combine swath sequence (dry).

Figure 2 and 3 represent common harvesting systems in Alberta. They both depend on weather conditions capable of drying either the swath or

the standing grain to a kernel moisture level low enough to insure safe storage, i.e. 14%.

Harvesting sequences represented by Figure 4 and 5 are not common harvesting systems in Alberta. However, they are common in countries with moist climates such as the British Isles and parts of the U.S.A. By harvesting grain at higher moisture levels, the effects of adverse weather are lessened to some extent. Johnson (46) and Arnold (2) suggest that modern combines are capable of threshing grain with moisture levels up to 25% without excessive grain loss and that optimal performance occurs between 17% and 22%.

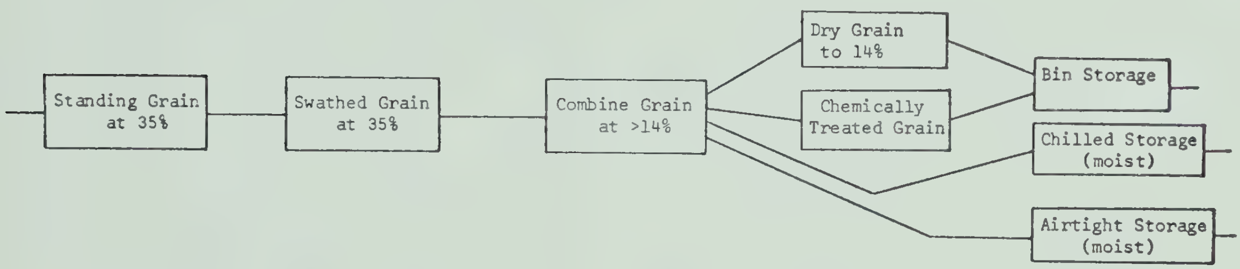

Figure 4. Combine swath sequence (moist).

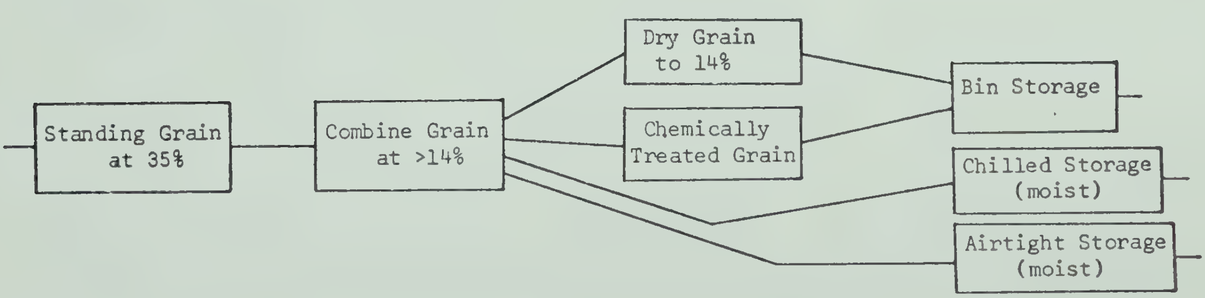

Figure 5. Straight combine sequence (moist).

Programming of the four harvesting systems in this study was carried

out using the General Purpose Simulation System/360 (83). The program is given in Appendix A.

7. PARAMETERS OF THE MODELS

Simulation techniques, being a relatively new approach to solving farm management problems, suffer from lack of proven variable interrelationships and recorded data. In order to develop a satisfactory model, some relationships in the simulations are made by logical assumption and others by observations of limited data. These relationships are treated by probability functions or are assumed to be constant.

7.1 Farm Location

The distance between Northern and Southern Alberta farming areas emphasizes the assumption that climatic effects on farming operations in various regions of the province probably will be different. While considering the time required for simulations and the availability of data, three areas were chosen. Beaverlodge, Lacombe and Lethbridge were used to represent Northern, Central and Southern Alberta respectively.

7.2 Farm Size

For the results of simulation to be more meaningful, three farm sizes were chosen for each district. In accordance with most farming practice, part of the total cultivated acreage is left fallow each year. A production cost study (67) in 1961-63 recorded that approximately 70% of the total cultivated acreage was seeded to grain in the Peace River and Red Deer districts while 50% was seeded in the Lethbridge district. Table 1 gives the average cultivated acreage and average yearly grain acreage for each area as recorded by the Alberta Department of Agriculture (47) in 1966.

TABLE 1: CULTIVATED ACREAGES USED IN SIMULATION MODELS.

Location	Cultivated Acreages	Cropped Acreages/Year
Beaverlodge	400	280
	640	450
	1145	1000
Lacombe	340	240
	600	420
	1150	1000
Lethbridge	520	260
	1020	510
	1600	800

7.3 Harvesting Dates

The date of spring seeding and the fluctuating weather conditions of the growing season influence the date at which the grain will reach maturity. To account for the fluctuating dates of grain maturity, probability distributions of harvest starting dates were used in the simulation models. Canada Department of Agriculture data provided a distribution for the Beaverlodge area (34). Distributions for Lacombe and Lethbridge were determined from estimates of a longtime farmer of each area (16 ,78).

Termination of harvesting operations may occur because of continuous unsatisfactory weather. Termination dates were determined arbitrarily from observations of weather records. The criterion used was defined by any precipitation which occured immediately before

or during periods of continuous below freezing average daily temperatures.

The distributions of Figure 6 are the average starting and terminating dates for the areas and do not include individual cases which may appear outside the range of fluctuation.

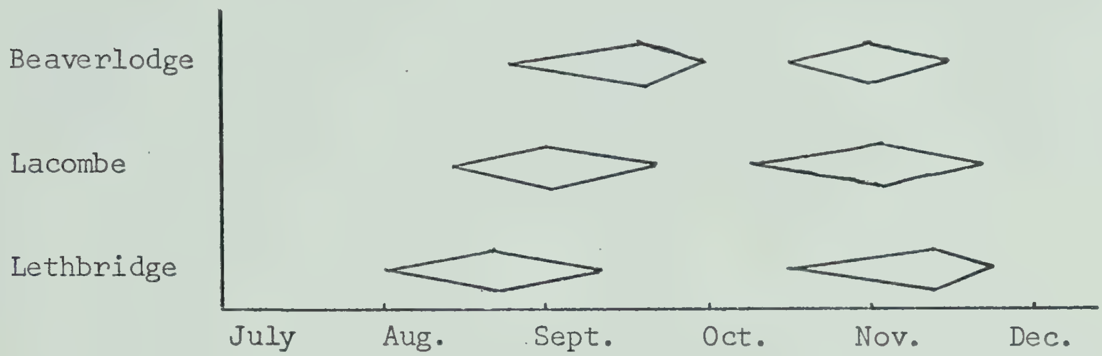

Figure 6. Harvest starting and termination dates.

7.4 Weather Conditions

The functioning of the simulation model requires daily determination of moisture change in the grain plant. The first attempt to simulate weather and its associated moisture change proved to be unsatisfactory and is discussed in a later section.

Plant maturation studies (22,23) have indicated that rate of moisture loss varies considerably with changes in weather and the time of year. To account for variation in the rate of moisture change, distribution functions were estimated for the months of August, September, October and November and are shown in Table 2. These rates are used for all three areas. Because of the differences in harvest starting dates, the average drying rate will be greater for the Lethbridge area than for the Beaverlodge area. This is not considered unrealistic.

TABLE 2: ESTIMATED DAILY DRYING RATES OF STANDING WHEAT.

Month	Mean Drying Rate	Range of Drying
August	4.24%	-8.50 to 16.75
September	3.75%	-11.25 to 18.75
October	2.66%	-15.25 to 20.50
November	1.90%	-18.00 to 22.00

7.5 Yield of Grain

Variation in yield will occur from district to district and from year to year. Average yields (51) for the years 1960-66 are given in Table 3. These census division averages tend to underestimate the amount of variation observed for an individual farm. Range of yields published from a survey taken in 1961-63 (67) were used to increase the variance of the distribution functions.

TABLE 3: YIELD DISTRIBUTIONS OF WHEAT.

Location	Mean Yield (bu/ac)	Range
Beaverlodge	21.1	10.5-36.5
Lacombe	28.1	8.3-50.5
Lethbridge	22.8	7.5-32.4

7.6 Storage of Grain

7.6.1 Dry Storage

Storing grain in a dry condition is a popular method on the Prairies. Materials handling engineers have developed plans for a large and varied selection of dry grain handling and storage systems. The value of a particular system to the farming operation is best determined by the individual since different systems vary in capital costs, flexibility, adaptability and efficiency. Only the cost of storing the grain has been considered in evaluating the different harvesting procedures. Cost of storage must consider economies of scale (77).

TABLE 4: ESTIMATED DRY GRAIN STORAGE COST.

Capacity (bu)	Cost (¢/bu/yr)*
1,000	2.5
2,000	2.25
3,000	1.90
5,000	1.50
24,000	1.40

* Calculated using building life of 20 years for a steel bin.

7.6.2 Aerated, Chilled and Refrigerated Storage

Aeration of stored grain is common in the United States. It is used to cool the center of grain bins and thereby prevent moisture migration. Both in the United States (74) and in Europe (3,12) refrigeration equipment has been combined with aeration equipment to

permit grain to be cooled quickly to prevent spoilage. The fact that fall and winter temperatures are relatively cool on the Prairies prompted Moysey (63) to investigate the possibility of replacing the costly refrigeration unit with natural air cooling. He concluded that in northern parts of the prairies, natural air could be used for cooling after the first week in September. Although his investigation only dealt with the Saskatoon area, his approach could be applied to other areas of the Prairies. The number of cooling hours available, grain moisture content, and the capacity of the aeration system would determine the possible use of this method in such areas. Dry bin storage can easily be converted to an aeration system by the addition of air ducts and a fan. Chilled grain would have to be dried or fed before warm weather arrives to prevent spoilage.

7.6.3 Airtight Storage

Airtight storage facilities have been available for a number of years but the high initial investment has limited their acceptance on the Prairies. Moist grain can be stored safely in such structures but can only be used for feeding purposes upon removal. The various types of airtight storage structures vary in capital and maintenance costs. The economic feasibility of this method of storage will depend on the type and size of the farming operation.

TABLE 5: ESTIMATED COSTS OF TWO SEALED STORAGE SYSTEMS.

Butyl Products Limited*			
Capacity of storage unit	2200 bu		27,500 bu
Cost of butyl rubber bag	$1200		$12,000
Estimated bag life		7 years	
Estimated cost/bu/yr	7.1¢		6.2¢
Harvestore Feeding Systems**			
Capacity of storage unit	7400 bu		25,500 bu
Cost of glass-lined steel tower silo	$13,100		$37,000
Depreciation life		20 years	
Estimated cost/bu/yr	8.8¢		7.2¢

* Canadian Distributor, Cooper Division of Agropharm Ltd., Lasalle, P.Q.

** ALBERTA HARVESTORE Feeding Systems Ltd., Edmonton, Alberta

7.7 Moist Grain Treatments

Moist grain can be prepared for storage by reducing its moisture content to a safe storage level or by treating grain with an organic acid prior to storage.

7.7.1 Grain Drying

There are several methods for drying damp grain. The use of natural air for in-storage drying provides an inexpensive system which is capable of drying several thousand bushels. The success of such a system will depend on the amount of moisture to be removed, the rate of moisture removal, and the climate during the drying period. Such a method was investigated by Moysey and Wilde (62). With the addition of small amounts of heat to the aeration system, the effects of adverse climate on drying can be nullified (38).

Other methods of grain drying include the batch and continuous flow

driers. These consist of large heated air machines that dry small quantities of grain relatively quickly. Such machines are expensive and incur higher operating costs than in-storage drying systems. However, since each method has its advantages and disadvantages, their value will depend on the individual farm operation. The in-storage drying system is included in the simulation models outlined in this present study. The approximate cost of drying grain at various moisture levels (29) is given in Table 6.

TABLE 6: ESTIMATED COSTS OF IN-STORAGE DRYING OF WHEAT.

Moisture Content (%)	Cost (¢/bu)
14	0
16	4
18	8
20	12
22	16
25	22

7.7.2 Chemical Treatment

A relatively new approach to damp grain storage is the use of chemical treatments. Costs and rates of application of such a treatment as calculated by the manufacturer of one commercially available product* are listed in table 7.

* Chemstor, manufactured by Chemcel Ltd., Edmonton, Alberta.

TABLE 7: CHEMICAL TREATMENT COSTS AND APPLICATION RATES FOR MOIST GRAIN STORAGE.

Moisture Content (%)	Rate (lb/bu)	Cost (¢/bu)
15	.30	5.7
16	.33	6.3
17	.35	6.6
18	.40	7.6
19	.43	8.2
20	.45	8.6
21	.48	9.1
22	.50	9.5
23	.55	10.5
24	.58	11.0
25	.60	11.4

7.8 Harvesting Penalties

During the course of the harvest season, certain physical and economic losses or penalties may be incurred. These are separated into three main groups.

7.8.1 Grain Losses

Dodds (20) classified grain losses into two types; (a) natural loss and (b) mechanical loss. Natural loss may be caused by wind, rain, insects, birds, and animals and is affected by the shattering character of the wheat variety. Mechanical loss was further divided into reel and cutterbar losses, pick-up losses and threshing losses.

Natural, reel and cutterbar losses increase as the standing grain matures, natural loss being the largest single grain loss in the field during harvest. Pick-up losses in swathed grain appeared relatively constant throughout the moisture range (Figure 7). Johnson (46), concluded that it is possible, with proper machine adjustment, to thresh grain up to 25% moisture content while maintaining an acceptable level of 1½% threshing loss. Dodds (20) also concluded that threshing and separating loss was negligible when considering the other losses.

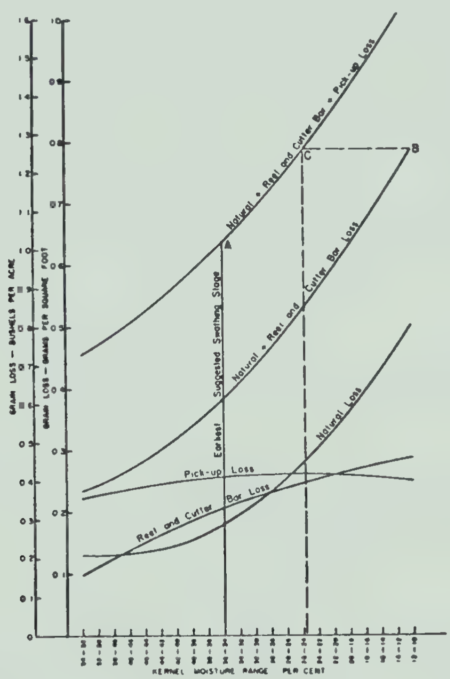

Figure 7. Trends of natural and mechanical losses of wheat when harvested at different stages of maturity.

Natural loss of standing grain will continue to accumulate until the grain is harvested. Johnson (46) observed that with each day delay there was approximately 12 lb/acre less grain available for harvesting. Observations made by Dodds (24) at Swift Current seem to indicate that this loss is not proportional to yield. A grain loss of 10 lb/acre/day after the 14% moisture level has been reached is used for the simulation

models in this study. Values presented in Figure 7 are used for the other losses.

7.8.2 Losses Due to Weathering

There has been very little work done on changes in grain quality due to weathering. Johnson (46) suggested a delay in grain harvesting will result in a test weight loss of about 0.23 lb/bu/day. Although there was a slight loss in dry matter, most of the test weight reduction was due to alternate wetting and drying which wrinkled the bran and resulted in poor packing of the kernels. Other quality tests concerning germination and baking seemed unaffected. Johnson concluded that the time mature grain stands in the field does not significantly alter the quality as long as grain is handled properly during and after harvest.

The Canada Grain Act (60) grades the quality of wheat according to:

1) weight per measured bushel
2) % by weight of hard vitreous kernels
3) degree of soundness
4) amount of foreign material present.

Although the minimum and maximum levels for each requirement are specified, much of the assessment is done by visual appraisal. It is normally assumed that the variation in wheat grades is a result of the quality of the growing and harvest seasons and the effectiveness of the operation of the combine. However, little research has been done to quantitatively substantiate this assumption. Change in wheat grade during the harvest season, therefore, is not included as a harvesting penalty by the simulation model.

7.8.3 Penalties for Incomplete Harvest.

7.8.3.1 Over-winter Loss

The consequences of leaving the grain over winter will be 100% loss for standing grain and approximately 10%-30% (7) loss for swathed grain. This loss will depend on the winter conditions and the degree of rodent infestation. Swaths made from a good stand of grain usually survive the winter better than swaths from a thin crop. Further loss may result from early sprouting, parts of the field lying under water, and the greater difficulty in picking up the swath during spring harvest. Individual observation of grain loss may exceed the range suggested.

7.8.3.2 Lost Opportunity

The presence of unthreshed grain in the field eliminates the opportunity for consequent farming operations such as cultivation and fall fertilizer applications. If livestock are included in the farm enterprise, fall grazing and retrieval of the straw is lost. These considerations may be important to the individual operation but have been omitted from the models because of difficulties in establishing economic values.

7.9 Working Hours

The number of hours available for combining each day depends on weather conditions, mechanical breakdowns and available labor. The diurnal fluctuations of temperature, humidity, and other weather characteristics limit combining dry grain to hours of the day when conditions are favorable. This daily variation in combining hours has been estimated monthly and treated by probability functions in the simulation models (Table 8).

TABLE 8: ESTIMATED MONTHLY VARIATIONS IN COMBINING HOURS PER DAY.

Month	Mean Hours Available Dry	Mean Hours Available Moist	Range	Average Day Length
August	10	13	±4	14.8
September	8	11	±4	12.6
October	6	9	±4	10.6
November	4	7	±4	8.7

Combining damp grain is not greatly affected by the diurnal fluctuation in weather conditions, consequently more time will be available for combining each day.

There are no provisions made in the programming of the systems to include harvesting conditions where both dry and moist grain would be combined during the same day. In order to meet this requirement, hourly calculations would be needed. The type of information required for hourly simulations is not presently available.

7.10 Combining Capacity

The rate at which grain can be threshed will depend on the level of grain loss which the farmer is willing to accept. This is usually about 3% of the yield or 1 bushel per acre. The largest proportion of this loss occurs over the straw walkers; shoe and cylinder losses account for the remaining threshing losses (65).

Feed rates and grain/straw weight ratios are the two major factors affecting grain threshing losses. Figures 8, 9, and 10 indicate the relationships between these variables.

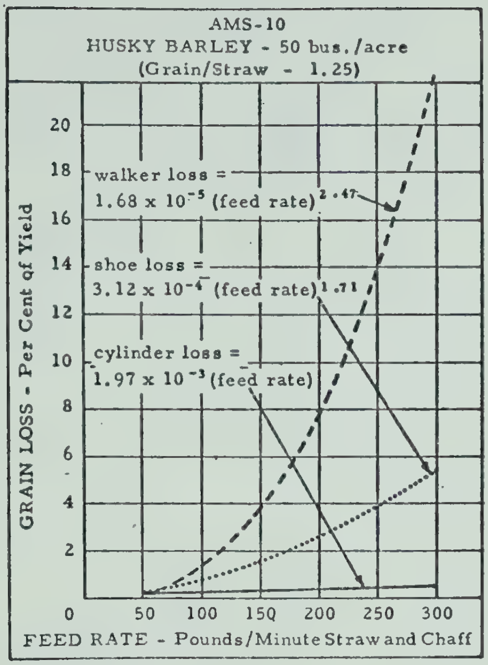

Figure 8. Distribution of losses for a standard combine in a crop of barley.

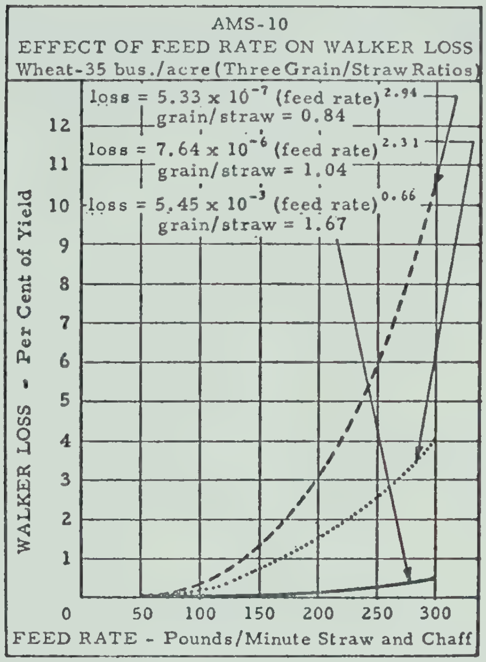

Figure 9. Effect of 3 grain/straw ratios on walker loss of the standard combine.

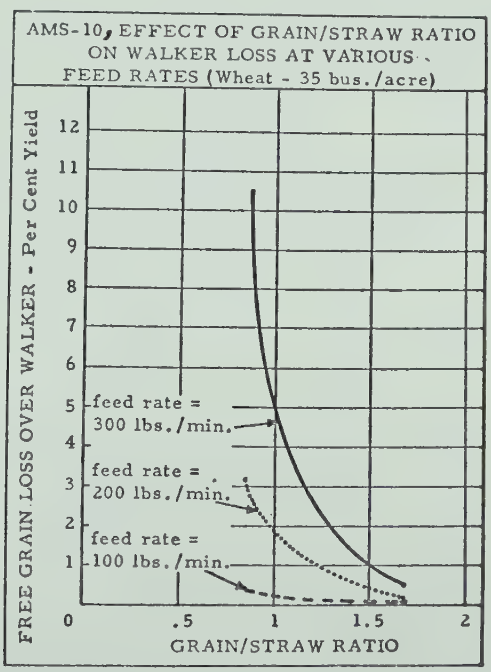

Figure 10. Effect of grain/straw ratios on walker loss of the standard combine. (65)

MacHardy (53) used several physical dimensions of combines to develop an empirical equation to compare their capacities. It takes the form:

$$Y = 3\left[\frac{W}{192} + \frac{B^{3/2}*L}{38,600} + \frac{S}{7,400}\right]$$

where

Y = field capacity in long tons/hr

W = cylinder width in inches

B = body width in inches

L = straw walker length in inches

S = combined chaffer and sieve area in square inches.

Specifications from 50 combines most likely to be found in operation on todays farms were used to classify these machines into six size groups according to MacHardy's formula. These groups are set out in Table 9.

TABLE 9: GROUPING OF COMBINE CAPACITIES AND EXAMPLES OF EACH GROUP

Group	Capacity short ton/hr*	Capacity lbs/min†	Example**
1	7.9	260	JD730, NH995
2	7.2	240	JD105, MF510, IHC915
3	5.8	195	JD630, MF410, IHC503
4	5.0	155	JD95, MF92, IHC403
5	4.0	135	JD55, MF82, IHC303
6	2.9	95	JD45, MF72

* short ton = 1.1 long ton

** JD = John Deere, NH = New Holland, MF = Massey Ferguson, IHC = International Harvester Co.

† = pounds per minute of straw and chaff.

Year-to-year variations in growing conditions result in variations of grain/straw weight ratios. Random grain/straw ratios between 0.6 and 1.8 are used in the simulation models. This range does not include every possibility as uncommon ratios may occur outside this range.

Combining rates (bu/hr) may be calculated for each combine capacity size and grain/straw ratio (Table 10).

TABLE 10: A REPRESENTATIVE SAMPLE OF COMBINING RATES IN BUSHELS PER HOUR FOR WHEAT.

Capacity	Grain/Straw Ratio					
lb/min	.6	.8	1	1.25	1.5	1.8
260	156	208	260	325	390	470
240	145	193	240	300	360	430
195	117	156	195	245	293	350
155	93	124	155	194	232	279
135	81	108	135	169	203	244
95	57	76	95	119	142	170

Daily combining rates are determined by multipling bushels per hour by the hours available for combining each day.

8. RESULTS AND DISCUSSION

8.1 Definition of Terms

Clarification of the terminology used in subsequent sections of this thesis is provided by the following definitions.

TOTAL DAYS - the number of days that were available for harvesting, including maturation days and bad days.

MATURATION DAYS - the number of days that were required to mature standing or swathed grain at 35% moisture to either 25% or 14%.

BAD DAYS - the number of days when combining was stopped due to unfavorable combining conditions.

% COMPLETION - the number of years out of 100 years when the total acreage to be harvested was completed.

BUSHELS LEFT - the total number of bushels left in the field because harvesting could not be completed.

DRY BU. HARVESTED - the number of bushels harvested dry (<14%)

MOIST BU. HARVESTED - the number of bushels harvested between 14% - 25% moisture.

GRAIN LOSS - the number of bushels attributed to natural and mechanical losses (see Section 7.8).

COST OF DRYING - drying costs in dollars, calculated using rates in Section 7.7.1.

COST OF CHEMICAL - cost in dollars, calculated using rates in Section 7.7.2.

8.2 Weather/Kernel Moisture Relationships

As stated previously, input requirements for the simulation models are on a daily basis. Previous work done in the Department of Agricultural Engineering, University of Alberta, has followed the approach of determining favorable or unfavorable working days from weather observations and using these probability distributions of 'good' and 'bad' days to simulate a sequence of favorable and unfavorable working days (72). Since harvesting operations are dependent on grain moisture conditions, an attempt was made to use this criterion to determine working and non-working days. If a relationship between weather variables and moisture change in the grain kernel could be established, the estimation approach of good and bad days would not be needed. An attempt therefore was made in a preliminary study to establish such a relationship.

Observations of moisture levels through grain maturation and harvesting periods has been made at Swift Current Research Station for 9 years, (95 observations). This daily recorded drop or gain in grain kernel moisture content and the associated weather conditions were used to develop regression equations which would be capable of predicting moisture change when given certain weather variables. If this approach had been successful, these equations could have been used with observed weather records from the three areas in Alberta to establish drying trends for those areas. This is a procedure similar to that used by Baire and Robertson (4) for estimation of daily latent evaporation.

Weather records available for the 3 areas concerned included maximum and minimum temperature, sunshine hours, wind velocities, precipitation and, either dewpoint temperatures or relative humidities. Missing relative humidity or dewpoint data and vapor pressure differences

were calculated using equations presented by Brooker (8). Day length and solar energy were calculated using a program written by Robertson and Russell (69).

The following regression equations were calculated using a computer program (32).

July 16 - August 20

Y1 = -.0176*VA1*SE-2.884*(VA2**3)*VPD+8.976*ALOG(VA2)-10.462*TMX +.296*R+3.723*S/DL-.189*SE+13.58*VA1-10.482*(2*RA+.00001)+ 10.898*TDB+5.282*TR+104.210

August 20 - September 30

Y2 = -42.670*X1-.6527*ALOG(RA+.00001)=3.941*DL+5.22*RH+.00002* (W^3)*VPD+2.324*TMX-193.380*VPD-4.373*TDP+99.642*ALOG(W*VPD) +42.986

where:

Y1 and Y2 = change in kernel moisture content, in %

VA1 = ALOG(2*RA+.00001)

VA2 = W*.01

SE = solar energy in cal/cm^2

VPD = vapor pressure deficit in mb

TMX = maximum temperature in ^oF

RE = relative humidity

S = sunshine hours in hours

DL = day length in hours

RA = precipitation in inches

W = wind in mpd

TDB = mean daily temperature in ^oF

TR = temperature range in ^oF

$X1 = ALOG(W^3)$

TDP = dew point temperature in ^{o}F.

Equation Y1 is based on 33 observations. The squared multiple correlation coefficient (R^2) is .57. Equation Y2 is based on 62 observations. The R^2 is .65. The low R^2 suggest that some important variables are missing from the regression. Weather variables alone do not account for all the variation in kernel moisture change. It is possible that inclusion of such factors as soil moisture, swath density or grain stand density and variety of grain might improve the equations fit. Another possibility is that daily measurements are not sufficiently frequent to provide a realistic picture of moisture changes. Preliminary simulation studies of hourly moisture change in wheat have been attempted by Brüick (9) in Sweden with reasonable success.

Although the accuracy of prediction of the regression equations was low for Swift Current, weather from the Alberta stations was used in the hope of at least obtaining mean drying rates. This would have allowed a comparison to be made of the drying rates for the three areas. However, the results were not meaningful and the entire approach had to be abandoned.

A better understanding of the interrelationships associated with grain maturation and natural drying and much more complete data on the parameters concerned are required before this approach may be successfully applied.

8.3 Simulations

The results of each simulated 'harvesting season' are stored by the GPSS/360 program and printed in tabular format upon termination of the simulation run. An example of such a table is shown in Appendix B. The GPSS program has an allotment for 30 such tables. Simulation of the four systems simultaneously restricted the quantity of data retrieved about each method. The data in Appendix C has been condensed from the statistical output of each simulation run. Each run was made using a different combine capacity and/or acreage. A total of 54 simulation runs were needed to account for the three locations, three farm sizes in each location and the six combine capacities for each farm size.

The primary objective of this study was to develop simulation models of harvesting systems that accurately duplicate the functioning of the real systems. Determination of optimal combinations of sub-systems was not considered in this study because of the large number of alternative combinations involved and the lack of economic data relating to many harvesting operations. The capabilities of the simulation models in aiding management decisions will be demonstrated using a hypothetical farming situation.

Figures 11 - 19 substantiate the logical assumptions

1. that the capacity of the combine will effect percentage completion,
2. that size of the acreage will effect percentage completion,
3. that moist grain harvesting systems will be completed before dry grain harvesting systems, and
4. that the practise of swathing grain increases the chances of completion.

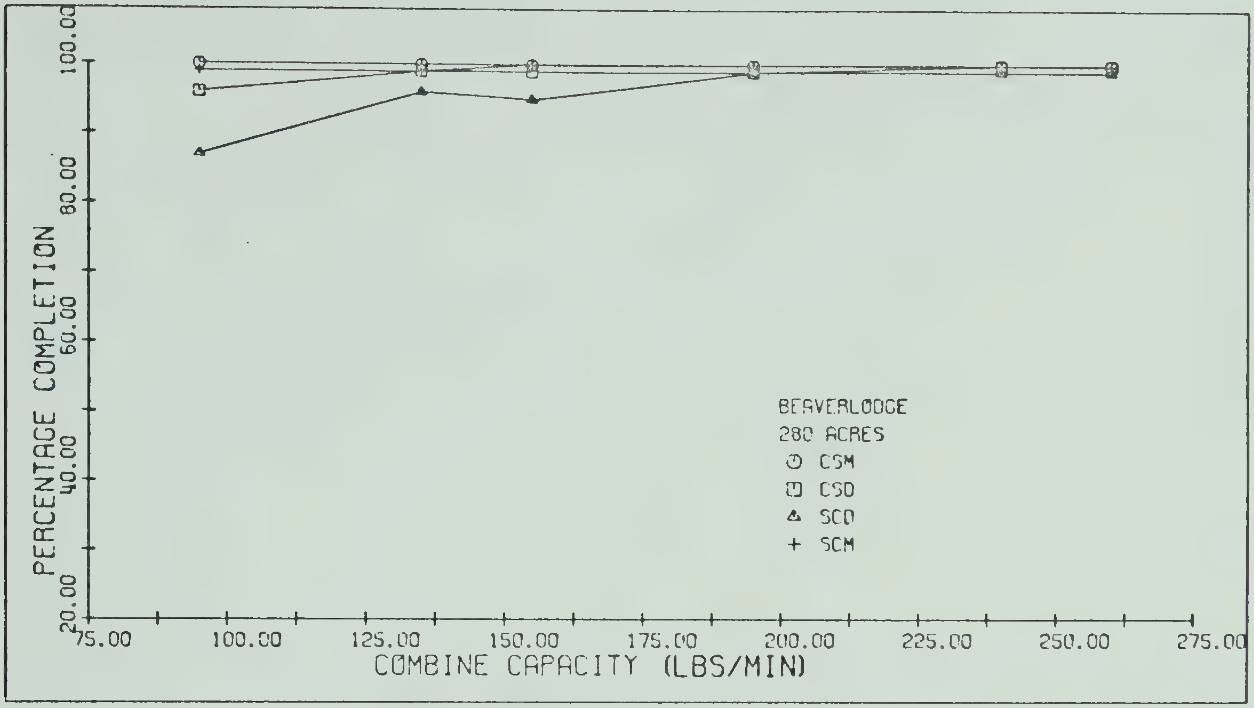

Figure 11. Computed harvest completion of 280 acres in Beaverlodge area.

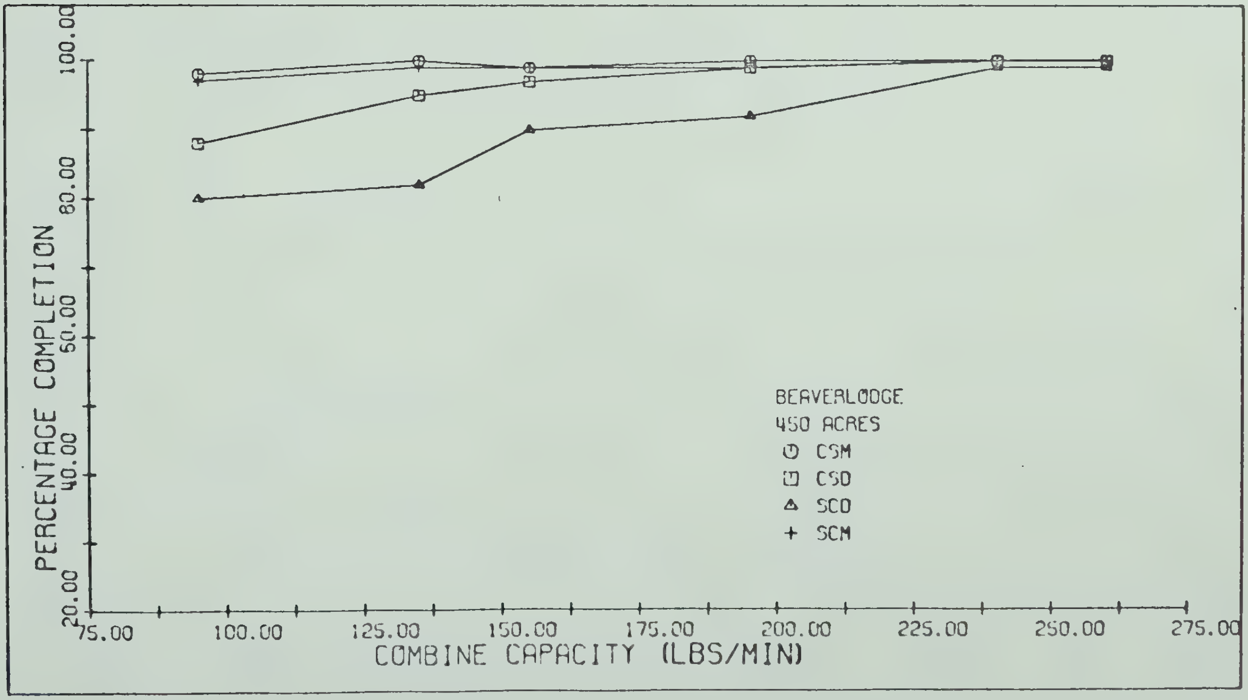

Figure 12. Computed harvest completion of 450 acres in Beaverlodge area.

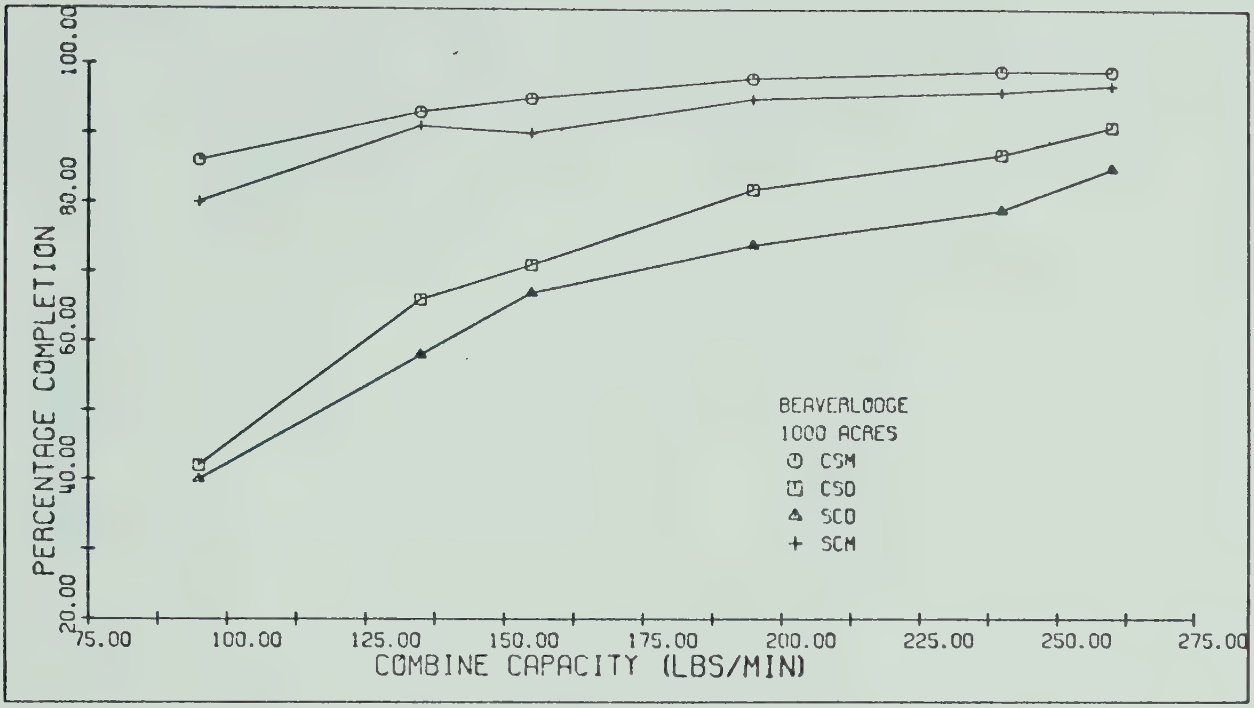

Figure 13. Computed harvest completion of 1000 acres in Beaverlodge area.

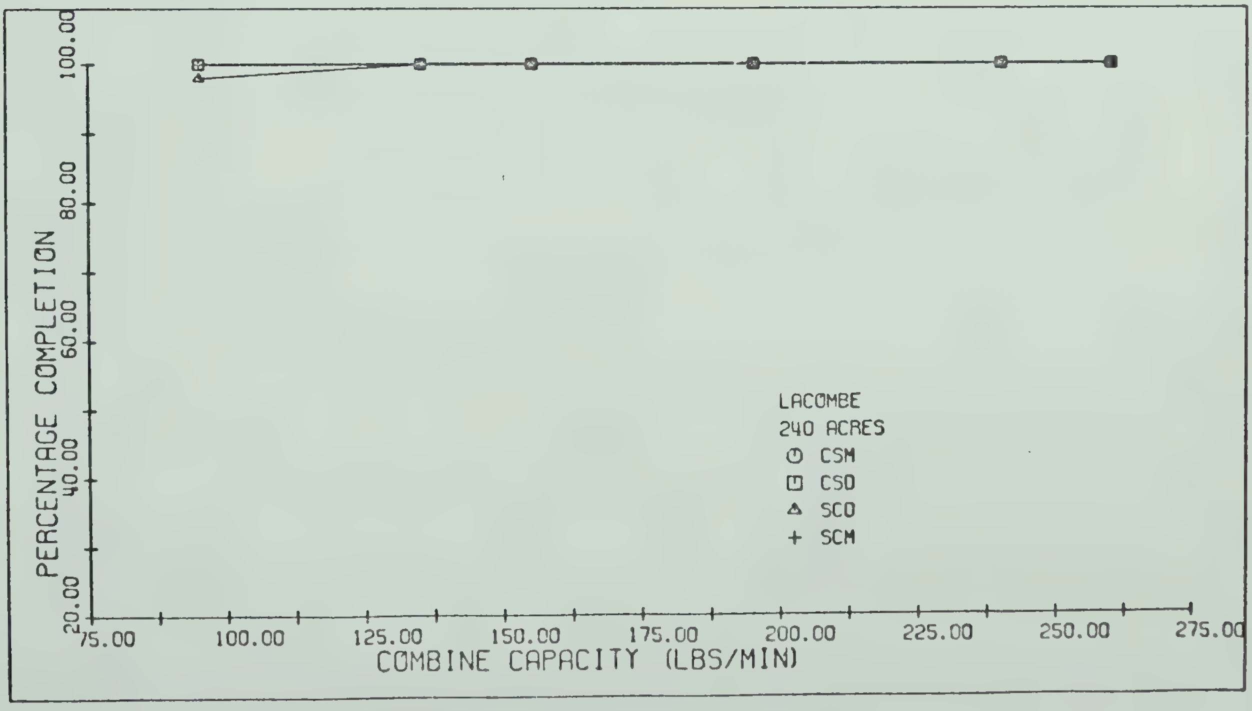

Figure 14. Computed harvest completion of 240 acres in Lacombe area.

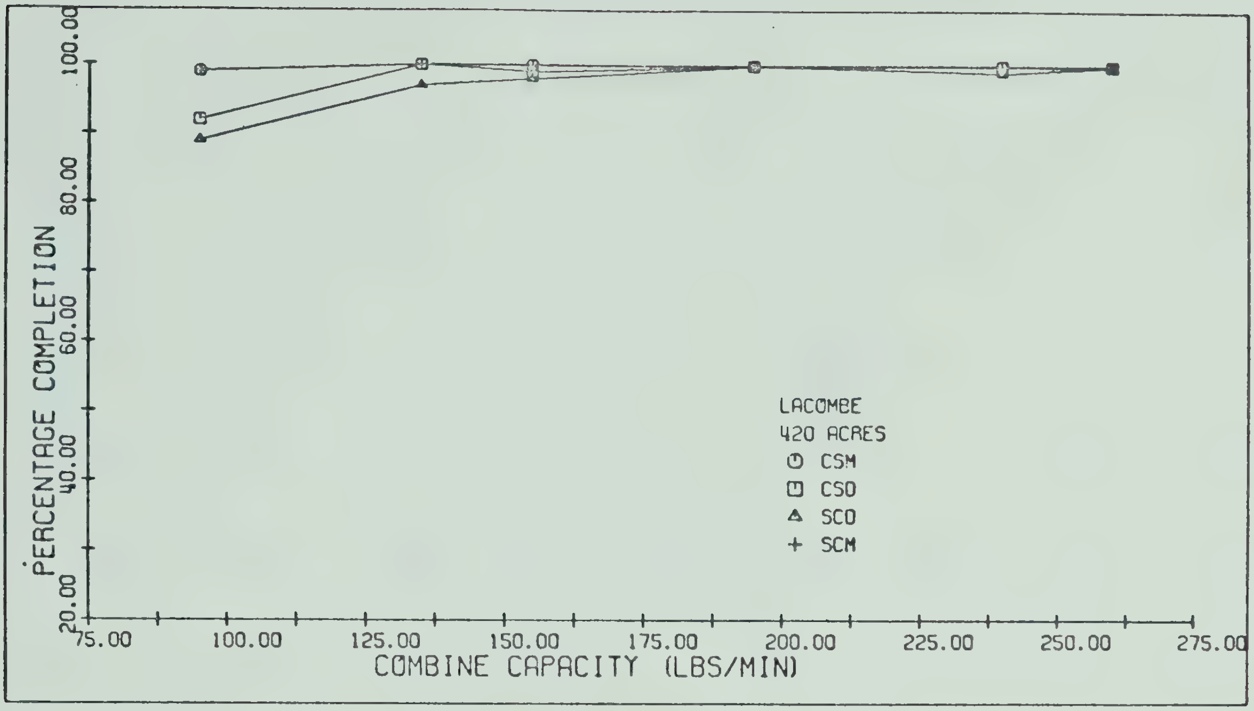

Figure 15. Computed harvest completion of 420 acres in Lacombe area.

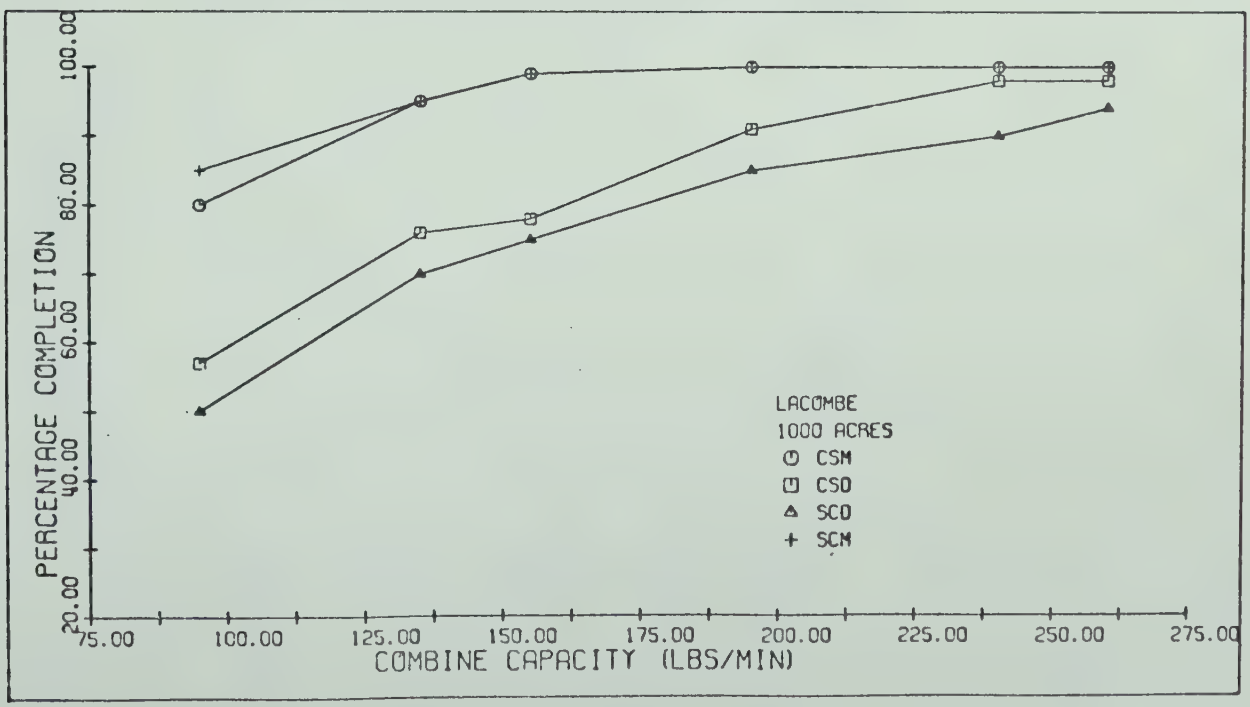

Figure 16. Computed harvest completion of 1000 acres in Lacombe area.

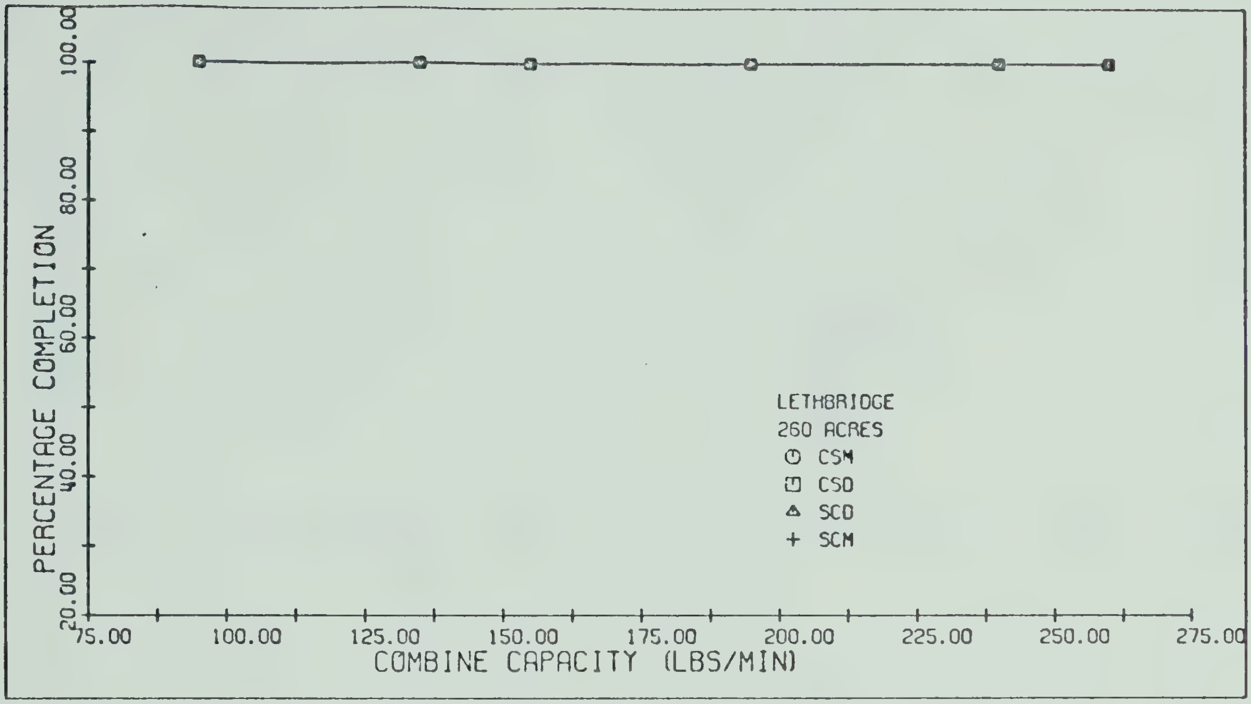

Figure 17. Computed harvest completion of 260 acres in Lethbridge area.

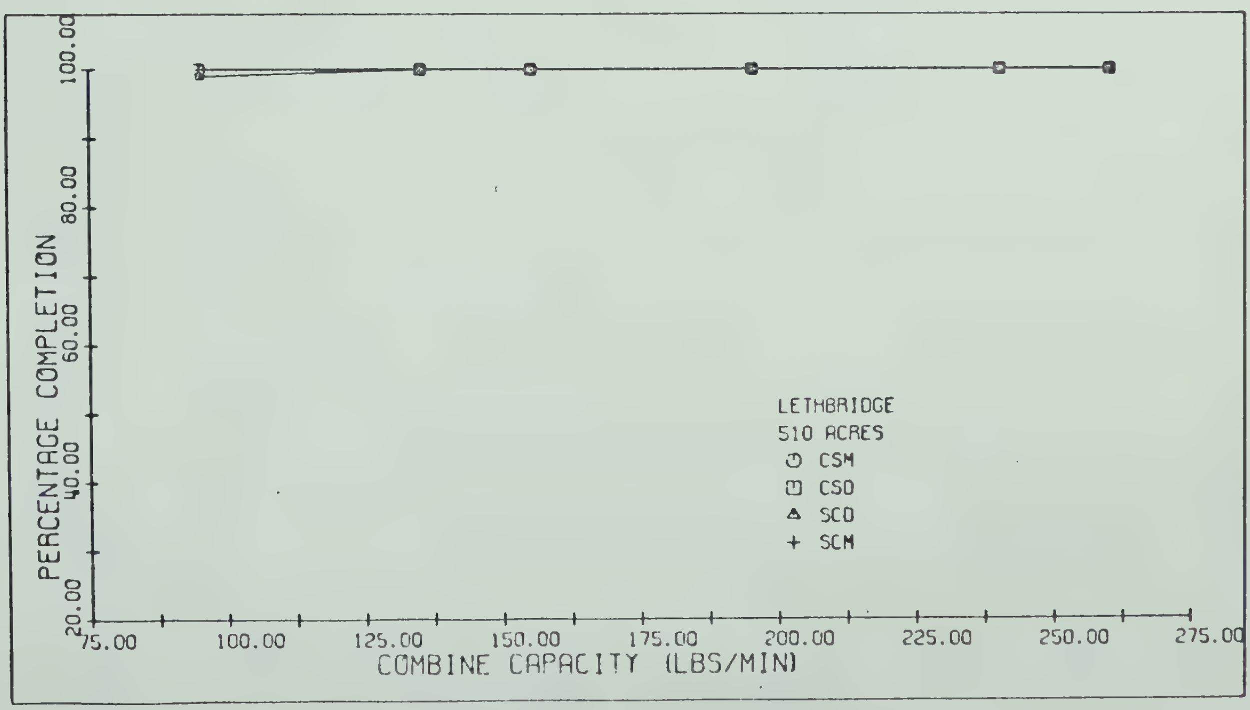

Figure 18. Computed harvest completion of 510 acres in Lethbridge area.

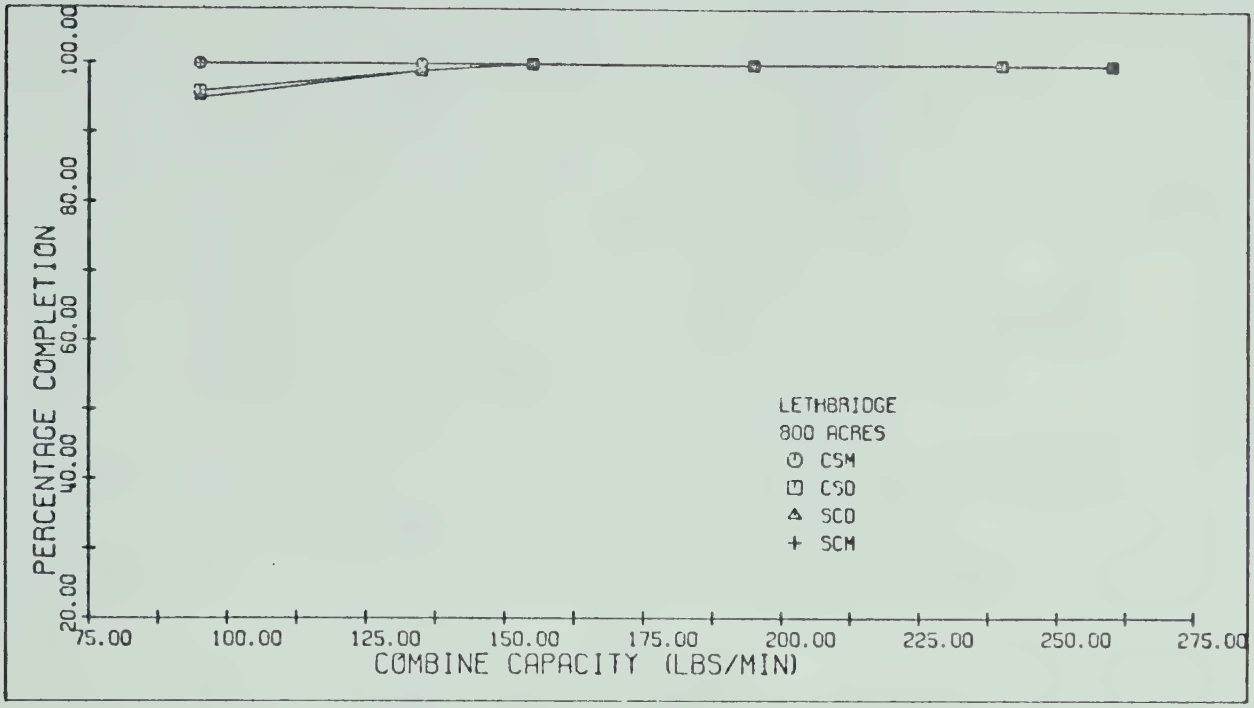

Figure 19. Computed harvest completion of 800 acres in Lethbridge area.

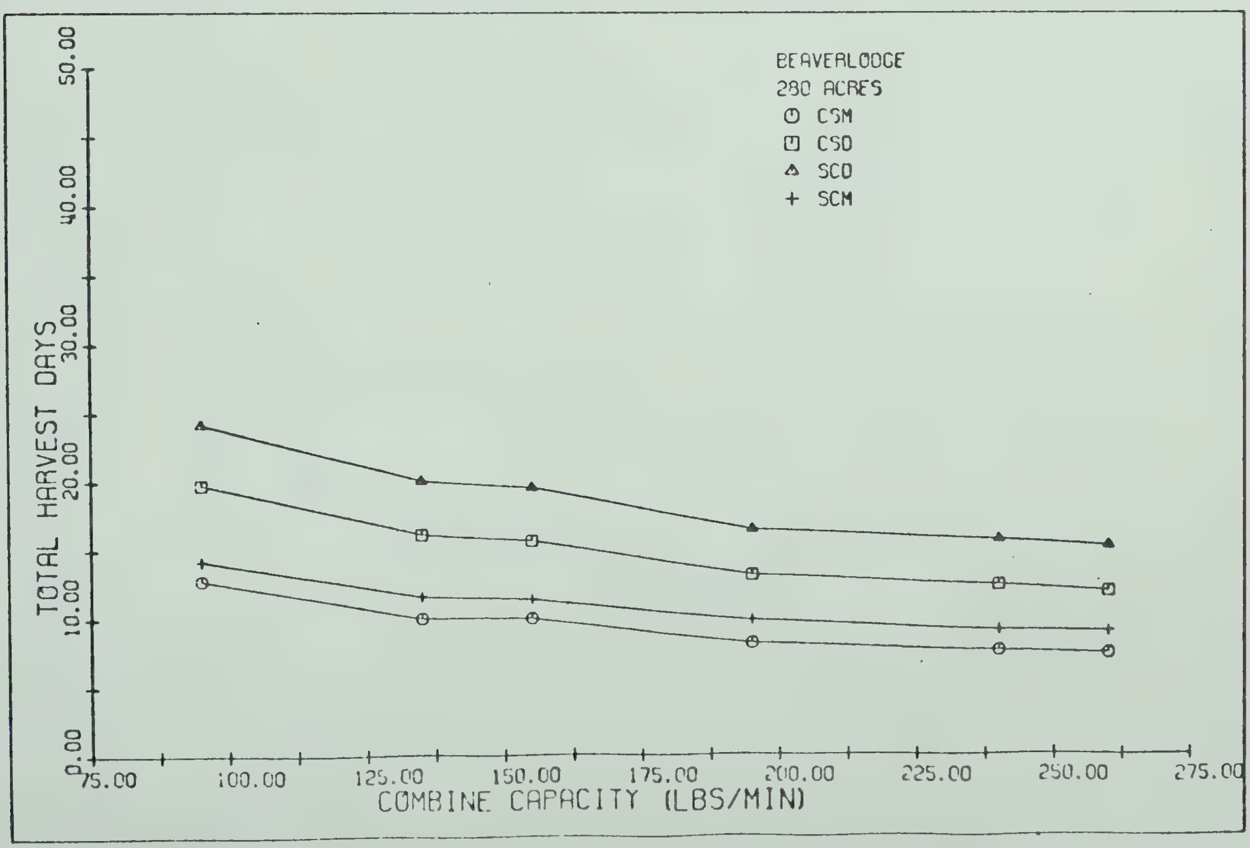

Figure 20. Computed total harvest days of 280 acres in Beaverlodge area.

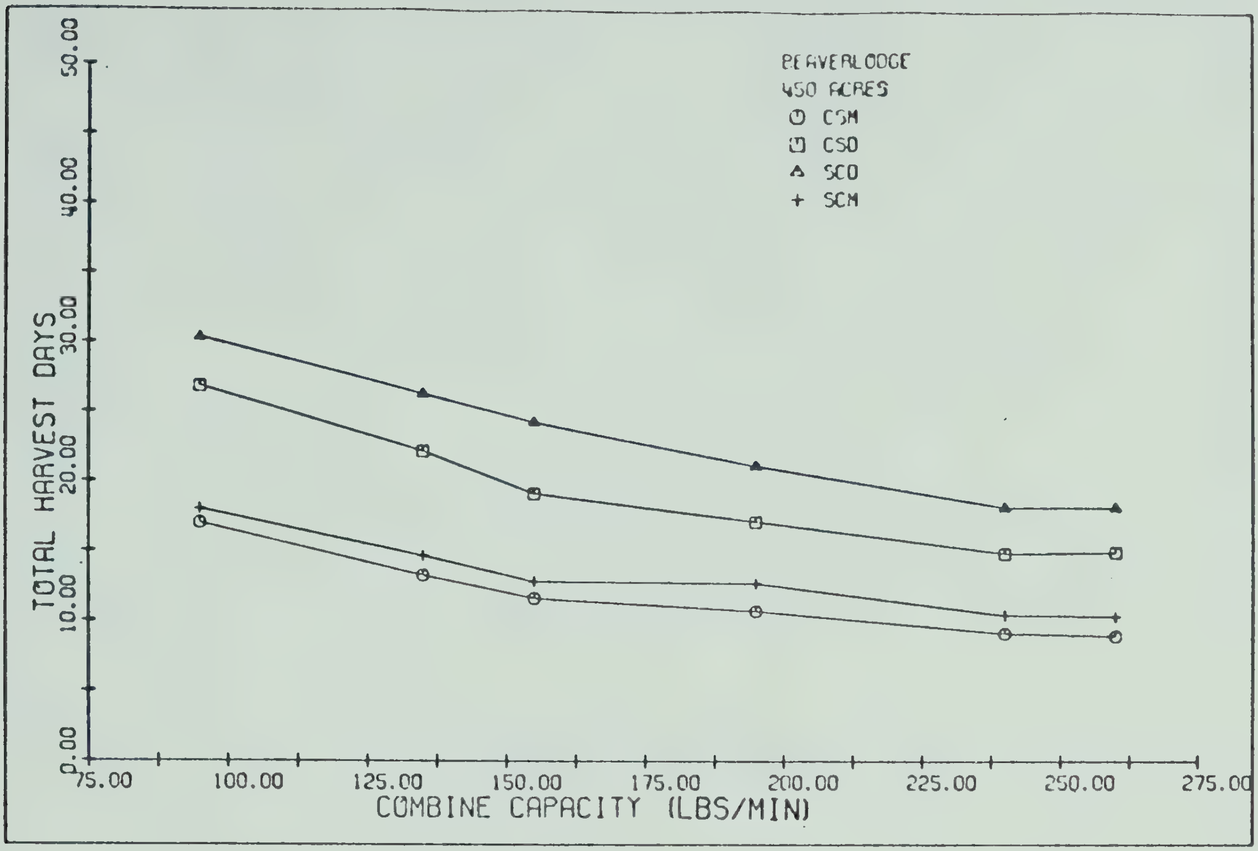

Figure 21. Computed total harvest days of 450 acres in Beaverlodge area.

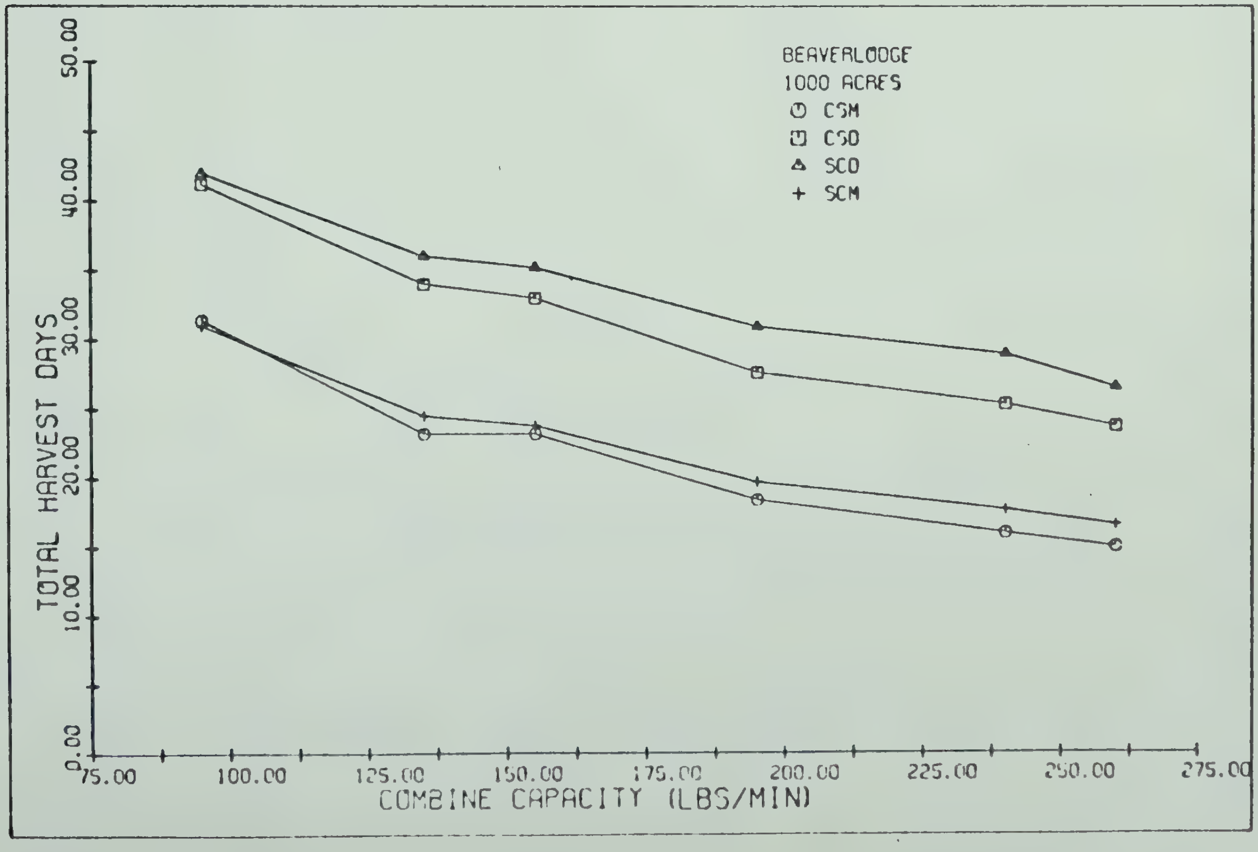

Figure 22. Computed total harvest days of 1000 acres in Beaverlodge area.

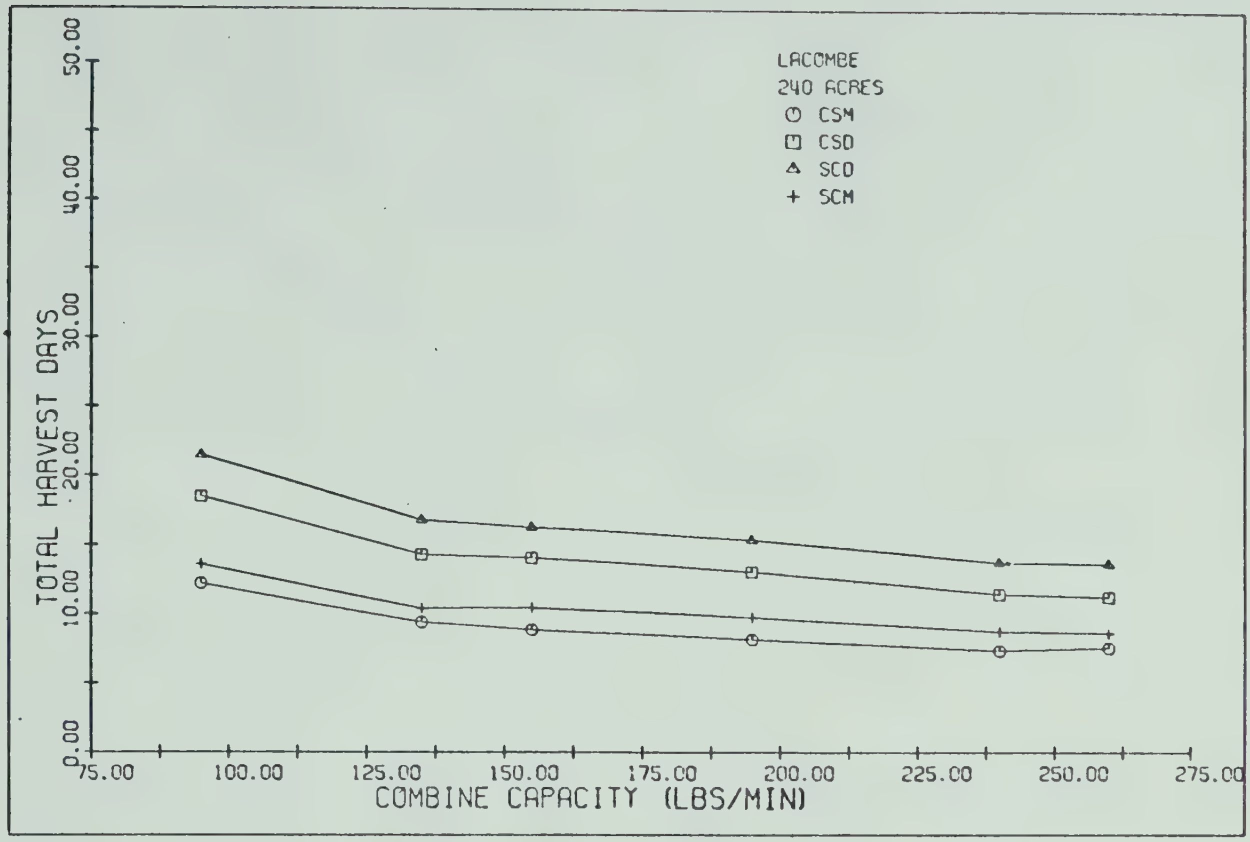

Figure 23. Computed total harvest days of 240 acres in Lacombe area.

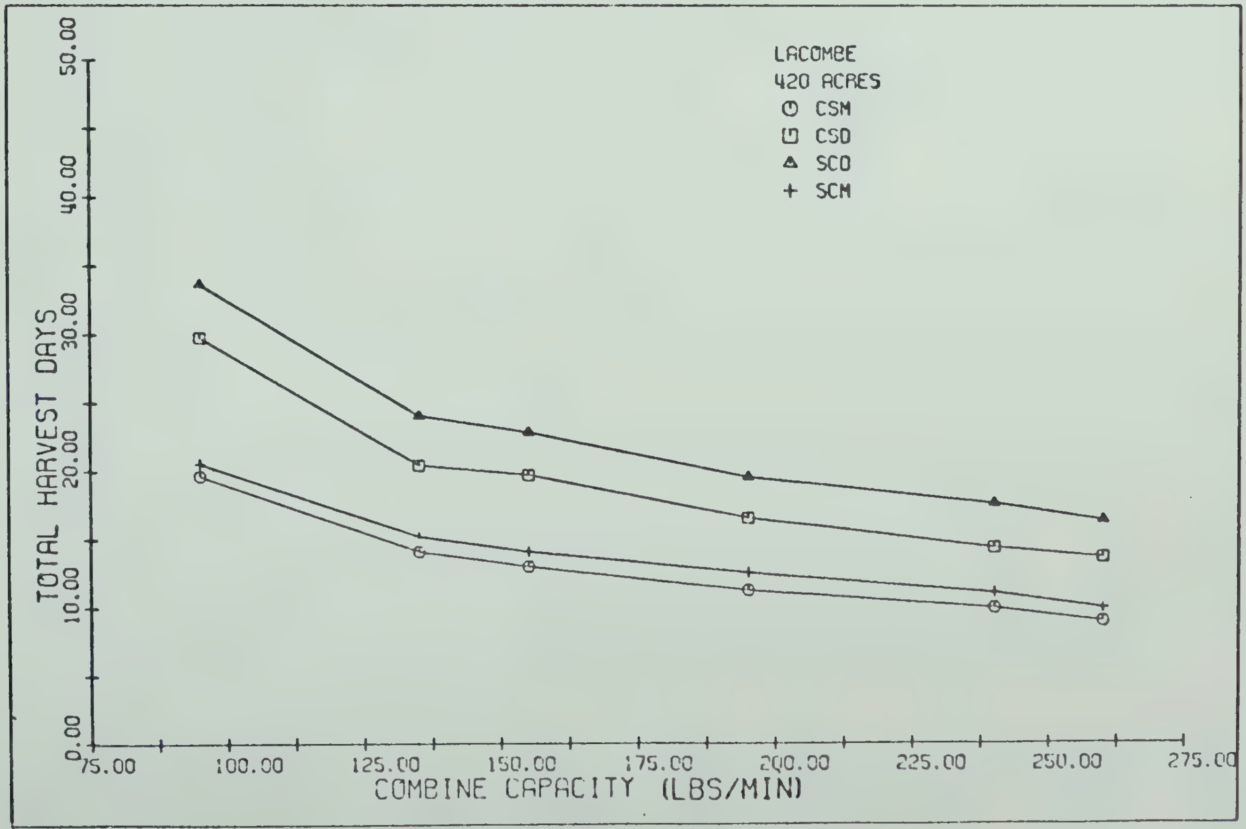

Figure 24. Computed total harvest days of 420 acres in Lacombe area.

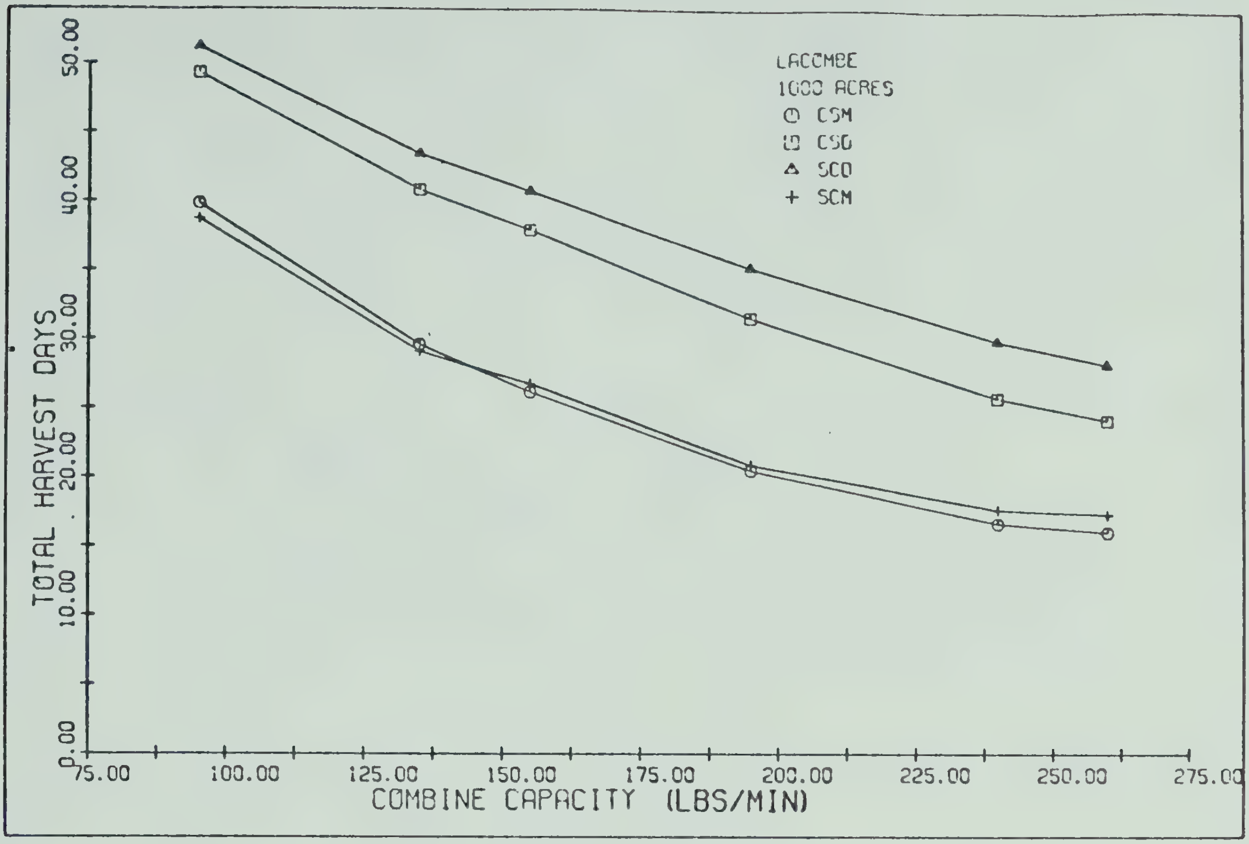

Figure 25. Computed total harvest days of 1000 acres in Lacombe area.

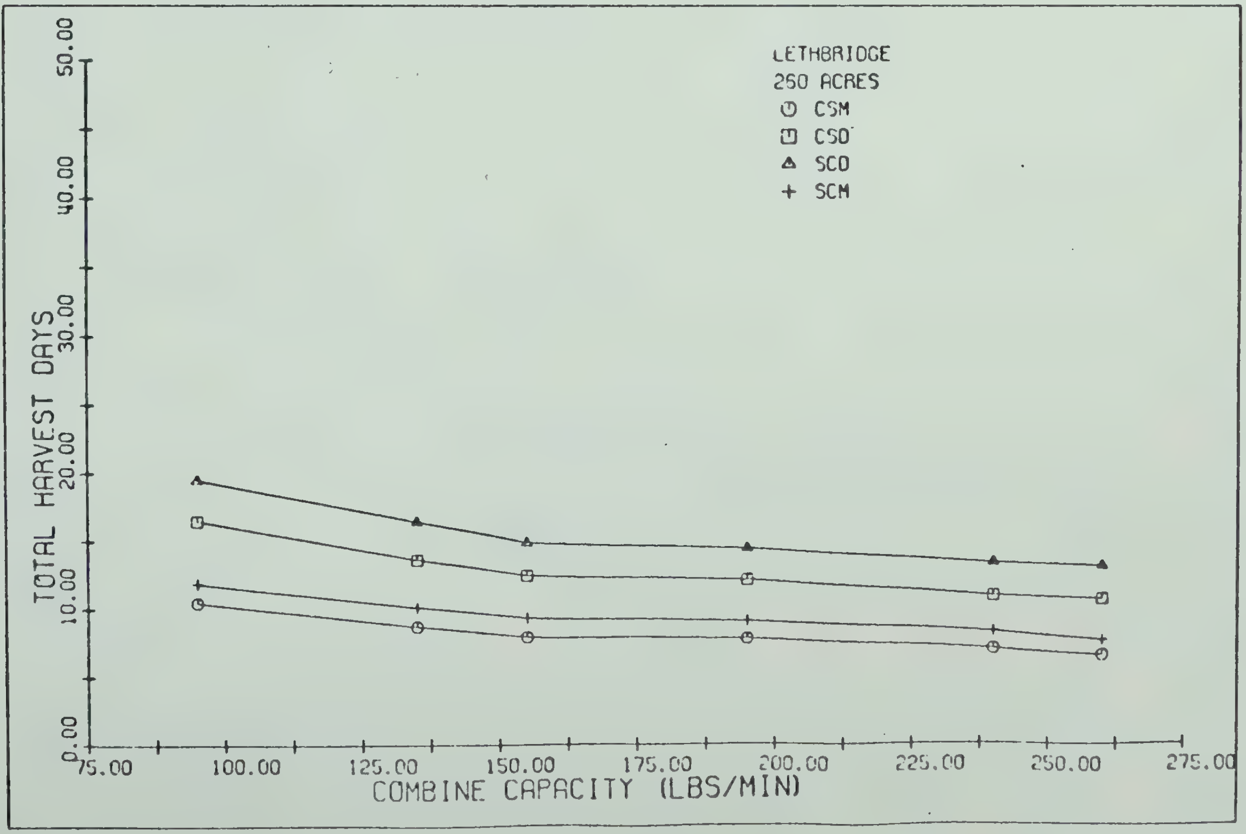

Figure 26. Computed total harvest dasy of 260 acres in Lethbridge area.

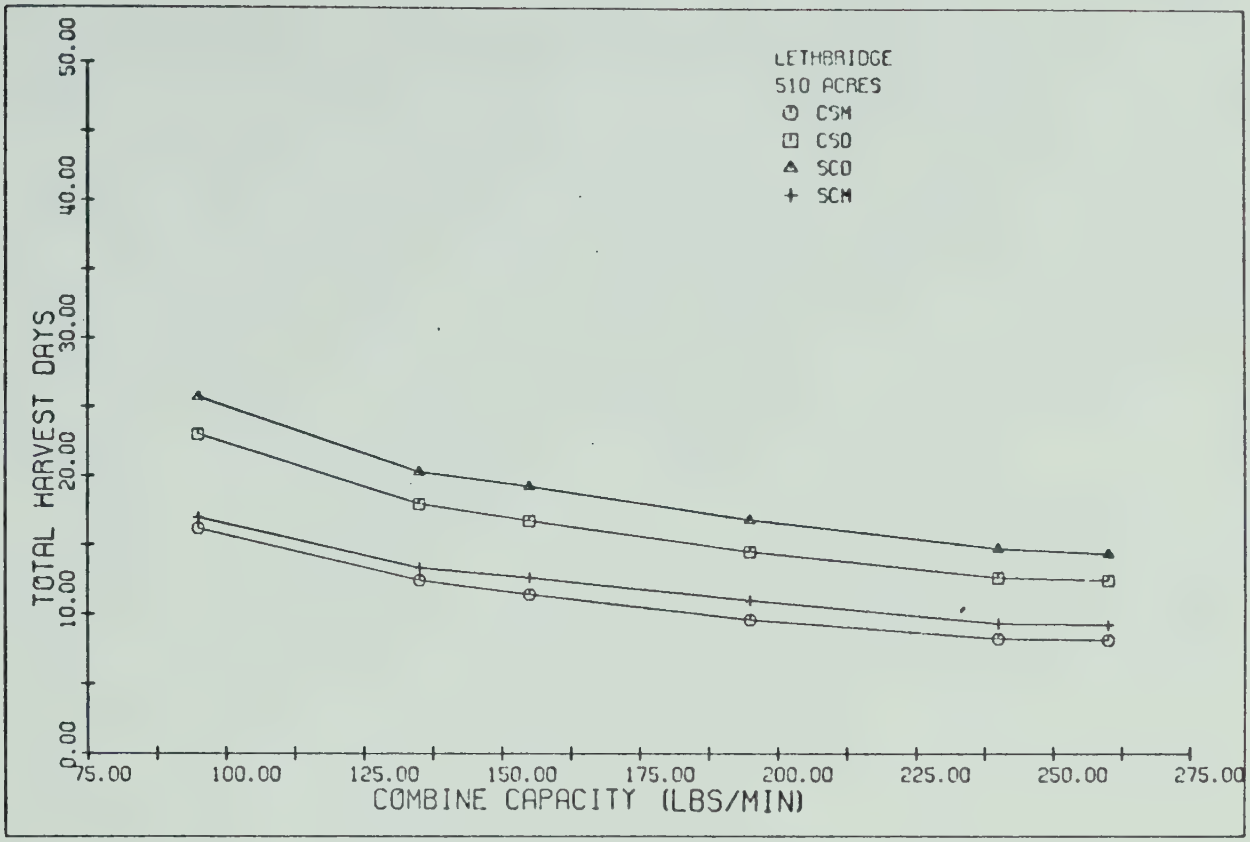

Figure 27. Computed total harvest days of 510 acres in Lethbridge area.

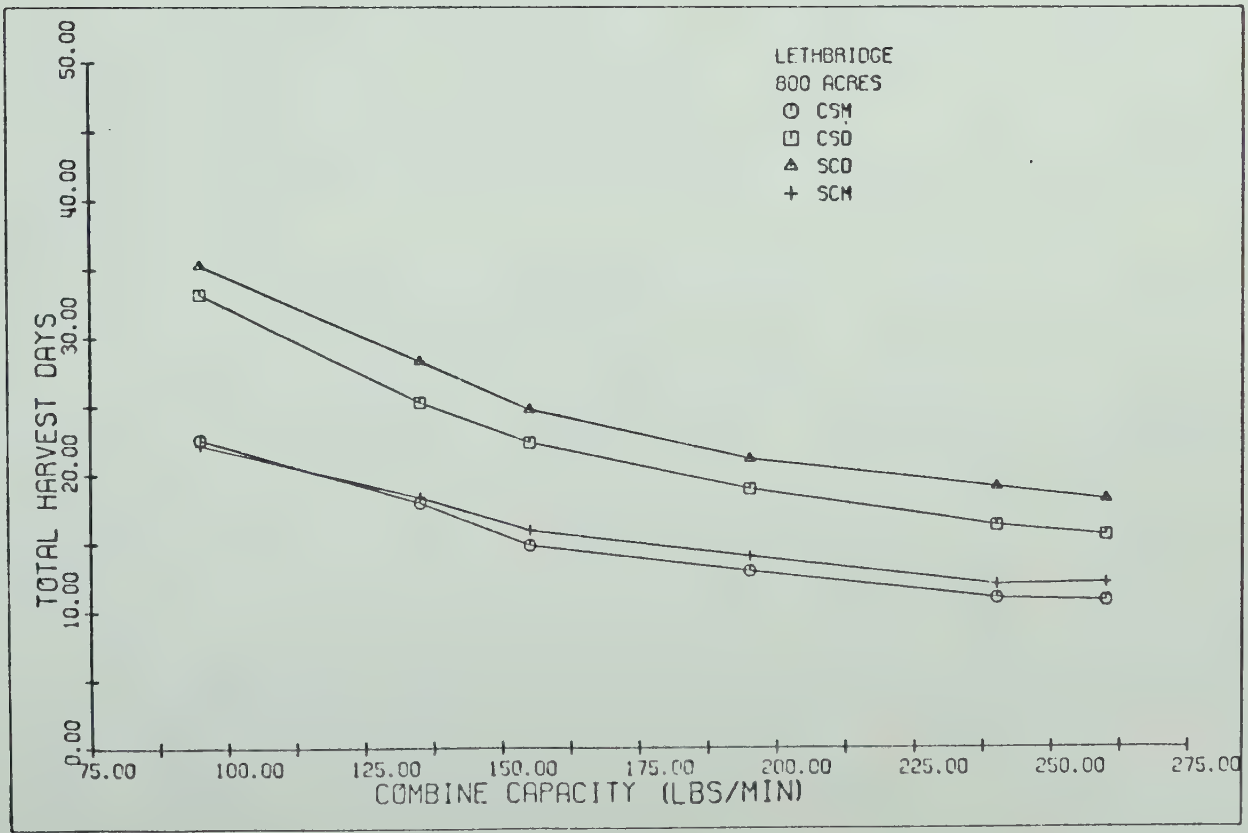

Figure 28. Computed total harvest days of 800 acres in Lethbridge area.

Reasons for different completion percentages can be found in Figures 20 - 28 and Tables 11 - 18. Completion percentages are a function of combine capacity, acres to be harvested and time available for harvesting. The time required to harvest a given grain acreage decreases as combine capacity increases. For a given combine capacity, the time required to harvest increases as acreage increases. An increase in harvesting time required decreases the chances of completion.

Table 11 shows the number of days that were required by each harvest system before combining could start in each area. Moist grain harvesting systems have an advantage. Drying rates for swathed grain have a 1% per day advantage over standing grain in the simulation. This shows up in the comparison of maturation days (Table 11).

Tables 12, 13 and 14 show the number of bad days experienced by each system. The dry grain harvesting systems are more vulnerable to unfavorable weather than the moist grain harvesting systems. The number of actual combining days (Tables 15, 16 & 17) varies with the capacity of the machine and the number of hours available for combining. The moist grain harvesting systems had a 3 hour per day advantage over the dry grain harvesting systems.

TABLE 11: COMPUTED NUMBER OF MATURATION DAYS FOR THE THREE FARM LOCATIONS.

Location	CSM*		CSD		SCD		SCM	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Beaverlodge	4.8	3.0	8.1	3.6	11.2	6.9	6.3	4.7
Lacombe	4.3	2.3	7.4	3.1	9.6	4.5	5.5	3.5
Lethbridge	4.1	2.2	7.2	2.8	9.2	4.2	5.3	3.6

* CSM - combine swath moist
CSD - combine swath dry
SCD - straight combine dry
SCM - straight combine moist.

TABLE 12: COMPUTED NUMBER OF BAD DAYS FOR BEAVERLODGE AREA.

Farm Size	Capacity	CSM		CSD		SCD		SCM	
Cult. acres/yr.	lb/min	Mean	SD	Mean	SD	Mean	SD	Mean	SD
280	95	.25	.77	2.5	3.7	4.1	6.9	.48	1.6
280	135	.16	.58	1.7	3.3	3.1	5.8	.56	1.4
280	155	.16	.71	1.7	3.3	2.8	5.2	.23	.76
280	195	.13	.51	.92	2.8	1.5	3.2	.48	2.3
280	240	.18	1.0	.59	1.1	1.3	2.3	.39	2.4
280	260	.13	.73	.54	1.4	1.2	3.0	.15	.46
450	95	.42	1.7	5.2	5.8	7.1	8.0	.75	1.8
450	135	.33	1.4	4.1	5.2	4.9	6.9	.67	1.8
450	155	.20	.80	3.0	4.6	5.1	7.1	.56	1.6
450	195	.24	.75	2.0	3.7	2.7	4.6	.65	2.2
450	240	.17	.67	1.5	2.7	2.8	5.0	.30	1.1
450	260	.18	.67	1.5	3.1	2.2	3.8	.32	1.0
1000	95	.98	1.94	9.7	6.6	11.5	7.5	2.1	4.7
1000	135	.67	1.3	7.5	6.5	9.6	8.2	1.9	4.5
1000	155	.58	1.8	7.4	6.7	8.8	7.8	1.7	4.5
1000	195	.52	1.5	5.0	6.0	7.2	7.6	1.2	3.0
1000	240	.39	1.3	4.7	5.5	6.5	7.4	1.2	3.4
1000	260	.33	.83	4.1	5.9	5.5	7.7	.96	3.4

TABLE 13: COMPUTED NUMBER OF BAD DAYS FOR LACOMBE AREA.

Farm Size	Capacity	CSM		CSD		SCD		SCM	
Cult. acres/yr.	lb/min	Mean	SD	Mean	SD	Mean	SD	Mean	SD
240	95	.16	.54	1.8	3.2	2.9	5.7	.31	.94
240	135	.07	.32	1.2	2.5	1.8	3.2	.23	.85
240	155	.08	.27	.92	2.0	1.5	2.7	.39	1.2
240	195	.25	1.3	.72	1.7	.84	1.8	.28	.94
240	240	.21	.71	.35	.90	.98	1.9	.20	.70
240	260	.13	.48	.47	1.5	.78	1.9	.14	.59
420	95	.17	.49	4.9	6.7	7.9	10.0	.39	1.1
420	135	.15	.50	2.0	3.5	3.8	5.7	.20	.71
420	155	.09	.32	2.3	4.4	3.3	5.6	.50	1.7
420	195	.28	1.0	1.2	1.8	2.0	4.4	.48	1.5
420	240	.09	.35	.88	2.0	1.8	4.6	.26	1.0
420	260	.13	.50	.73	1.7	1.5	2.9	.20	.83
1000	95	1.06	2.71	11.2	9.2	15.1	11.3	2.1	4.6
1000	135	.65	1.9	8.2	8.2	11.9	11.3	1.4	4.2
1000	155	.35	1.3	7.5	8.6	10.6	10.4	1.3	3.4
1000	195	.16	.44	5.7	7.3	8.6	10.6	.43	1.1
1000	240	.15	.59	3.8	5.6	6.4	8.5	.38	1.2
1000	260	.27	.88	3.12	4.81	5.21	7.6	.59	1.5

TABLE 14: COMPUTED NUMBER OF BAD DAYS FOR LETHBRIDGE AREA.

Farm Size	Capacity	CSM		CSD		SCD		SCM	
Cult. acres/yr.	lb/min	Mean	SD	Mean	SD	Mean	SD	Mean	SD
260	95	.17	.64	1.4	2.7	2.9	6.1	.34	1.1
260	135	.13	.54	.82	1.8	1.3	2.4	.48	1.7
260	155	.11	.40	.65	1.5	1.0	2.4	.35	1.1
260	195	.14	.45	.53	1.5	1.2	3.0	.09	.47
260	240	.08	.34	.33	1.3	.63	1.9	.09	.43
260	260	.05	.26	.40	.96	.80	2.1	.14	.59
510	95	.18	.72	1.9	3.3	3.4	6.0	.19	.69
510	135	.06	.31	1.3	2.4	1.8	3.1	.34	1.1
510	155	.11	.57	1.1	2.0	1.6	3.1	.40	1.1
510	195	.12	.64	.68	1.7	1.1	2.7	.24	.64
510	240	.07	.35	.69	1.5	.77	1.8	.04	.24
510	260	.04	.31	.41	.90	.57	1.2	.20	.86
800	95	.10	.41	5.0	7.0	6.9	9.3	.33	1.2
800	135	.05	.22	2.6	3.9	4.0	6.7	.22	.85
800	155	.16	.58	2.3	4.5	3.2	6.3	.29	.86
800	195	.07	.38	1.5	2.4	2.2	4.0	.15	.54
800	240	.04	.20	.98	1.9	1.72	3.5	.21	.54
800	260	.05	.41	.69	1.6	1.17	2.63	.23	.83

TABLE 15: EXAMPLE OF COMPUTED NUMBER OF ACTUAL HARVEST DAYS FOR BEAVERLODGE AREA.

Combine Capacity	280 Acres		450 Acres		1000 Acres	
	CSM	CSD	CSM	CSD	CSM	CSD
95	7.5	9.0	11.9	13.6	25.4	23.1
135	5.0	4.5	8.3	10.2	18.1	17.9
155	4.6	5.7	6.7	8.3	17.6	17.6
195	3.5	4.6	5.9	7.4	12.7	14.0
240	3.1	3.9	4.6	5.6	11.1	12.5
260	2.6	3.4	4.2	5.4	9.8	11.4

TABLE 16: EXAMPLE OF COMPUTED NUMBER OF ACTUAL HARVEST DAYS FOR LACOMBE AREA.

Combine Capacity	240 Acres		420 Acres		1000 Acres	
	CSM	CSD	CSM	CSD	CSM	CSD
95	7.8	11.1	15.3	17.4	34.1	30.4
135	5.5	6.4	9.3	10.9	24.8	25.3
155	4.7	5.8	8.7	10.2	21.4	22.8
195	3.7	5.6	6.8	7.9	16.3	18.6
240	3.0	3.8	5.5	6.4	12.4	14.6
260	2.9	3.5	4.8	5.9	11.7	13.5

TABLE 17: EXAMPLE OF COMPUTED NUMBER OF ACTUAL HARVEST DAYS FOR LETHBRIDGE AREA.

Combine Capacity	260 Acres		510 Acres		800 Acres	
	CSM	CSD	CSM	CSD	CSM	CSD
95	6.5	7.7	12.0	12.8	18.6	21.3
135	4.4	5.5	8.2	9.6	13.7	15.6
155	3.7	4.6	7.3	8.6	10.9	11.0
195	3.3	4.2	5.6	6.7	9.0	10.5
240	2.7	3.3	4.3	5.4	7.0	8.2
260	1.5	3.1	4.0	5.0	6.3	7.6

The summation of maturation days, bad days and actual combining days resulted in total harvesting days (Figures 19 - 28). Most of the difference in total days between systems is due to the variation in maturation days. The effects of bad days on total harvesting days decreased as combine capacity increased. This is indicated by the greater slopes of the curves in Figures 19 - 28 at the smaller capacity levels.

Output from the simulation models also includes the accumulated quantity of grain that was not combined over the 100 harvest seasons and the amount of grain lost due to natural and mechanical causes. These figures could provide a penalty factor for an economic evaluation of the alternative harvesting systems. Grain loss, as calculated by the models, represents 2 - 3% of the average grain yield.

The quantity of grain that reached storage was recorded under dry and moist grain harvested. The moist grain harvesting systems produced

more grain than the dry grain harvesting systems because of better completion percentages and lower grain losses. It was observed that the quantity of moist grain harvested increased as combine capacity increased. The reason for this is that the models were programmed to start combining operations as soon as the required grain moisture conditions were reached, regardless of how early in the season this occured. As a result, the larger capacity combines harvested more grain during the time the grain moisture was dropping from 25% to 14% than the smaller combines. This decision also resulted in higher drying and chemical costs for treatment of the moist grain.

From these results, moist grain harvesting systems do not appear to be competitive with dry grain harvesting systems when the chances for completion are similar for both systems. An advantage in favor of moist grain handling systems may appear where acreages are large enough to effect chances of completion, or where the opportunity costs of a longer harvest period outweigh the costs of treating moist grain.

8.4 Application of the Simulation Models.

Simulation techniques are not especially suited for determination of optimum combination of input variables but the results of simulation should provide the basic information needed for economic evaluation of certain management decisions. A hypothetical farm in the Beaverlodge area was used to test the validity of this premise. The yearly cropped acreage of the farm in question is assumed to have increased to 1000 acres and there is concern whether the present combine is sufficiently large to handle this increase. Approximately 10,000 bushels of grain are used for feed each winter. The farm operator has been considering moist grain systems as an alternative to increasing combine size. He estimates

that non-completion of harvest penalizes him 30% of the yield plus $1000 for the lost opportunity to carry out field work which requires seven days.

The various alternative farming decisions tested using the simulation model were:

1. retain combine capacity at 155 lb/min or increase it to 240 lb/min,
2. accept moist grain as soon as it can be satisfactorily threshed (25%) or wait until after October 5 before accepting moist grain.
3. either zero, 7 or 14 days for fall work requirement,
4. a choice of drying moist grain at a cost of 2¢/bu/% drop or using chilled storage to hold grain at a cost of .75¢/bu over winter.

The results of the 24 combinations are shown in Tables 18, 19 and 20. The figures presented in these tables do not constitute a detailed dollar budget for each alternative but do indicate a general economic comparison. The best harvesting system for the hypothetical situation appears to be an increase in combine capacity, straight combining of the moist grain as soon as possible and using the chilled storage method to hold this grain until it is fed (Table 19). If scarce capital rules out an increase in combine size, the next best solution is to combine swathed grain moist as soon as possible and then chill the grain.

If this farmer did not have an outlet for his moist grain, the best alternative is an increase in combine capacity and combining the swath dry. However, if the smaller combine were retained, combining the swath moist and drying the grain is the best solution. This difference probably

TABLE 18: EVALUATION OF HARVEST SYSTEMS WITH NO FALL WORK REQUIREMENT.

		Moist Grain Harvesting Decision					
		As Soon As Possible				After October 5	
		CSM	CSD	SCD	SCM	CSM	SCM
Combine 155 lb/min	Moist Bu. Harvested	8648			9875	6006	6959
	Dry Bushels Harvested	11656	17727	15246	8746	12850	9998
	Recovered Bushels	165	1970	-	-	1150	-
	Gross Return ($)*	20469	19697	15246	18621	20006	16957
	Completion Penalty ($)	50 (95)**	290(71)	330(67)	100(90)	170(83)	220 (78)
	Drying Cost ($)	906	-	-	1080	673	770
	Chilling Costs ($)	65	-	-	74	45	52
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Return (dry) ($)	18163	18057	14916	17441	17823	15967
	Net Return (chilled) ($)	19009	-	-	18447	18441	16685
Combine 240 lb/min	Moist Bu. Harvested	10582	-	-	12307	8691	9417
	Dry Bushels Harvested	9934	19399	17209	7464	11305	9174
	Recovered Bushels	10	765	-	-	390	-
	Gross Return ($)*	20526	20064	17209	19771	20386	18591
	Completion Penalty ($)	10 (99)	130 (87)	210 (79)	40 (96)	70 (93)	120 (88)
	Drying Cost ($)	1180	-	-	1429	1021	1125
	Chilling Costs ($)	80	-	-	93	65	71
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Return (dry) ($)	17986	18684	17999	18302	17915	17346
	Net Return (chilled) ($)	19086	-	-	19638	18901	18400

* @ $1.00/bu

** percentage completion

TABLE 19: EVALUATION OF HARVEST SYSTEMS WITH SEVEN DAYS FALL WORK REQUIREMENT.

		Moist Grain Harvesting Decision					
		As Soon As Possible				After October 5	
		CSM	CSD	SCD	SCM	CSM	SCM
Combine 155 lb/min	Moist Bu. Harvested	8589	-	-	9258	6345	6812
	Dry Bushels Harvested	11436	17859	15094	9279	12563	10469
	Recovered Bushels	360	1870	-	-	1120	-
	Gross Return ($) *	20385	19729	15094	18537	20028	17281
	Completion Penalty ($)	50 (95)**	340(66)	440(56)	70 (93)	160 (84)	240 (76)
	Drying Cost ($)	923	-	-	988	697	742
	Chilling Costs ($)	64	-	-	70	48	51
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Return (dry) ($)	18062	18039	14654	17479	17821	16299
	Net Return (chilled) ($)	18921			18397	18470	16990
Combine 240 lb/min	Moist Bu. Harvested	10521	-	-	12328	9136	9914
	Dry Bushels Harvested	9986	19527	17361	7686	11061	9145
	Recovered Bushels	19	673	-	-	210	-
	Gross Return ($) *	20526	20200	17361	20004	20407	19059
	Completion Penalty ($)	10 (99)	130(87)	250(75)	10(99)	40(96)	110(89)
	Drying Cost ($)	1149	-	-	1458	1026	1196
	Chilling Costs ($)	79	-	-	93	69	75
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Return (dry) ($)	18017	18720	17111	18536	17991	17753
	Net Return (chilled) ($)	19087			19901	18958	18874

* @ $1.00/bu

** percentage completion

TABLE 20: EVALUATION OF HARVEST SYSTEMS WITH 14 DAYS FALL WORK REQUIREMENT.

		Moist Grain Harvesting Decision					
		As Soon As Possible				After October 5	
		CSM	CSD	SCD	SCM	CSM	SCM
Combine 155 lb/min	Moist Bu. Harvested	9007	-	-	10286	7300	7768
	Dry Bushels Harvested	10981	16742	13676	8758	11680	9273
	Recovered Bushels	390	2660	-	-	1085	-
	Gross Return ($)*	20378	19402	13676	19044	20065	17041
	Completion Penalty ($)	120(88)	410(59)	520(48)	140(86)	210(79)	290(71)
	Drying Cost ($)	984	-	-	1153	822	912
	Chilling Costs ($)	68	-	-	78	55	58
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Return (dry) ($)	17924	17642	13156	17751	17683	15839
	Net Return (chilled) ($)	18840	-	-	18826	18450	16693
Combine 240 lb/min	Moist Bu. Harvested	10995	-	-	11917	9364	9770
	Dry Bushels Harvested	9529	18187	15720	7641	10364	8315
	Recovered Bushels	7	1790	-	-	550	-
	Gross Return ($)*	20531	19977	15720	18558	20278	18085
	Completion Penalty ($)	20(98)	220(78)	350(65)	80(92)	80(92)	180(82)
	Drying Cost ($)	1254	-	-	1458	1095	1199
	Chilling Costs ($)	83		-	90	70	73
	Swathing Cost ($)	1350	1350	-	-	1350	-
	Net Reutrn (dry) ($)	17907	18407	15370	17020	17753	16706
	Net Return (chilled) ($)	19078			18388	18778	17832

is a result of higher completion rates for the moist grain harvesting systems.

Another statistic that is relevant is completion percentages. The reliability of a particular system might influence its acceptance with another system over the long run. There would be less year-to-year variation of returns from the more reliable system.

The decision to accept moist grain only after October 5th lowers the drying and chilling costs but the completion percentage is also reduced sufficiently to nullify this effect. The short harvesting seasons in northern Alberta necessitates combining as soon as possible. This decision rule might produce significant results for farms located in central or southern Alberta.

From the example and the other simulation results, it appears that the cost of grain treatment and storage greatly effects the economic feasibility of each system. The benefits of higher completion percentages and greater total bushels harvested common to the moist grain harvesting systems can easily be destroyed by high grain treatment or storage costs. In the example, the relatively high cost of drying penalized some of the moist grain systems enough to reduce their acceptance. However, if these costs can be kept low, moist grain harvesting systems will have the advantage over dry systems.

Final evaluation of alternative harvesting systems must be made while considering the total farm operation. A more expensive treatment in one area might produce great savings in another area. Airtight storage might provide such an example. The higher cost of storage could possibly be offset by savings in time and cost of handling.

Again, it must be emphasized that the values presented in Tables

18, 19 and 20 are average results determined from 100 yearly observations. Deviation from these values can be expected and should be considered before actual implementation of any of the mentioned harvesting systems. Standard deviations are available for the models but have not been presented.

The small differences in average net return among the 4 systems suggests that no particular system has any great economic advantage over a large number of years. The reliability and success of each harvest system can be determined by observing the yearly deviations of net returns from the average. Systems with large deviations indicate some unreliability as to guaranteeing harvesting completion and consequently revenues. This fact may become of major importance where farm management requires a stable yearly income to continue operating.

9. CONCLUSIONS

The main objective of this study was to develop harvesting system models that could be used for simulation purposes. These models required sufficient flexibility to handle various combinations of farm location, farm size and combine capacity plus the unpredictable influences of growing conditions on grain production and of weather on combining operations. A total of 54 combinations experienced 100 harvesting seasons in the simulations generated.

The results of the simulations substantiated, with values, the logical assumptions that the capacity of the combine and the acreage harvested effects harvest completion percentages and that moist grain harvesting systems would be completed before dry grain harvesting systems.

The results from the application example indicate that the cost of grain treatment and storage greatly effects the economic feasibility of each system. An advantage in favor of moist grain handling systems may appear where acreages are large enough to effect chances of completion, or where the opportunity costs of a longer harvest period outweigh the cost of treating moist grain. Systems with large deviations indicate some unreliability as to guaranteeing harvest completion and consequently revenues.

The successful use of simulation techniques to solve agricultural harvesting problems is limited by a shortage of information pertaining to certain areas. The influence of weather variations on plant production and maturation and machine operations is one such area. The performance of combines in threshing grains with moisture contents greater than 15% is also needed.

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11. APPENDICES

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*LOC    OPERATION  A,B,C,D,E,F,G                    COMMENTS
        SIMULATE
        INITIAL    X1-X100,0
        INITIAL    X51,210          ACRES IN CROP
        INITIAL    X74,260          FEED RATE
        INITIAL    X53,33         %MC TO CSM
        INITIAL    X60,135  SWATH COST /ACRE
        INITIAL    X61,17      %MC TO CSD
        INITIAL    X62,17      % MC TO SCD
        INITIAL    X63,33      % MC TO SCM
  1     FUNCTION   RN1,C8   DRY RATE 1
CCO  -8     .060  -3    .145  0      .250  2     .720  7    .865  10
.950  13    1.00  18
  2     FUNCTION   RN2,C8   DRY RATE 2
CCO  -11    .060  -6    .160  -2     .300  1     .790  9    .880  12
.995  15    1.00  20
  3     FUNCTION   RN3,C8   DRY RATE  3
CCO  -15    .050  -10   .170  -5     .370  0     .735  8    .865  12
.950  16    1.00  22
  4     FUNCTION   RN4,C8  DRY RATE  4
CCO  -18    .04   -14   .110  -10    .314  -3    .718  8    .860  13
.956  18    1.00  23
  5     FUNCTION   RN5,C2   WORKING HOURS
0     6     1.00  15
  6     FUNCTION   RN5,C2   WORKING HOURS
C     1     1.00  8
  7     FUNCTION   RN5,C2            GRAIN / STRAW RATIO
C     6     1.00  18
   8    FUNCTION   RN6,C10   LETH. YIELD
C     0     .001  5     .03   10     .14   15    .400  21   .600  24
.80   27    .915  30    .99   32     1.00  40
   9    FUNCTION   RN7,C9   LETH. START DATE
0     212   .C75  220   .20   226    .355  230   .624  234  .751  237
.880  242   .92   248   1.00  253
   10   FUNCTION   RN8,C8   LETH. STOP DATE
0     288   .07   299   .140  304    .253  317   .450  315  .775  321
.900  325   1.C0  330
 17     FUNCTION   X56,C2            DRYING COSTS 2 /BU/%DROP
16    C     33    22
 18     FUNCTION   X58,C2      CHEM TREATMENT COST
16    0     32    11
        GENERATE   85,,,400
        LOGIC S    5
        LOGIC S    6
        LOGIC S    7
        LOGIC S    8
        SAVEVALUE  5,0
        SAVEVALUE  7,0
        SAVEVALUE  8,0
        SAVEVALUE  9,0
        SAVEVALUE  10,0
        SAVEVALUE  11,0
        SAVEVALUE  12,0
        SAVEVALUE  13,0
        SAVEVALUE  14,0
        SAVEVALUE  15,0
```

```
         SAVEVALUE  32,0
         SAVEVALUE  40,55
         SAVEVALUE  41,0
         SAVEVALUE  42,0
         SAVEVALUE  43,0
         SAVEVALUE  44,0
         SAVEVALUE  45,0
         SAVEVALUE  46,0
         SAVEVALUE  47,0
         SAVEVALUE  48,0
         SAVEVALUE  50,0
         SAVEVALUE  52,55
         SAVEVALUE  71,0
         SAVEVALUE  80,0
         SAVEVALUE  81,0
         SAVEVALUE  82,0
         SAVEVALUE  83,0
         SAVEVALUE  64,0
         SAVEVALUE  65,0
         SAVEVALUE  87,0
         SAVEVALUE  89,0
         SAVEVALUE  95,0
         SAVEVALUE  97,0
         SAVEVALUE  90,0
         SAVEVALUE  91,0
         SAVEVALUE  92,0
         SAVEVALUE  93,0
         SAVEVALUE  87,0
         SAVEVALUE  89,0
         SAVEVALUE  95,0
         SAVEVALUE  97,0
         SAVEVALUE  102,0
         SAVEVALUE  103,0
         SAVEVALUE  70,FN8            YIELD/ACRE
         SAVEVALUE  71,FN9            STARTING DATE
         SAVEVALUE  72,FN10           FINISHING DATE
         SAVEVALUE  73,FN7            GRAIN / STRAW RATIO
      30 FVARIABLE  X51*X70           TOTAL YIELD
         SAVEVALUE  5,V30
         SAVEVALUE  13,V30
         SAVEVALUE  41,V30
         SAVEVALUE  48,V30
   47    FVARIABLE  32*X51/100        SWATHING LOSS @ 35%
         SAVEVALUE  87,V47
         SAVEVALUE  89,X87
         SAVEVALUE  5-,V47
         SAVEVALUE  13,X5
   START ADVANCE    1
         TEST L     X71,K244,DRY2     PERIOD 1
         SAVEVALUE  4,FN1             MOISTURE CHANGE
         SAVEVALUE  100,FN5           HR/DAY COMBINE
         TRANSFER   ,DRY5
   DRY2  TEST L     X71,K274,DRY3     PERIOD  2
         SAVEVALUE  4,FN2             MOISTURE CHANGE
         SAVEVALUE  100,FN5           HR/DAY COMBINE
         SAVEVALUE  100-,2
         TRANSFER   ,DRY5
```

```
DRY3  TEST L      X71,K304,DRY4    PERIOD 3
      SAVEVALUE   4,FN3            MOISTURE CHANGE
      SAVEVALUE   100,FN5          HR/DAY COMBINE
      SAVEVALUE   100-,4
      TRANSFER    ,DRY5            PERIOD 4
DRY4  SAVEVALUE   4,FN4            MOISTURE CHANGE
      SAVEVALUE   100,FN6          HR/DAY COMBINE
 33   FVARIABLE   X74*X73*X100/(X70*10)
DRY5  SAVEVALUE   101,V33
34    FVARIABLE   X70*V33
      SAVEVALUE   54,V34
52    FVARIABLE   X100+K3
      SAVEVALUE   104,V52
54    FVARIABLE   X74*X73*X104/(X70*10)
      SAVEVALUE   110,V54          ACRES/DAT (MOIST)
53    FVARIABLE   X70*V54          BU/DAY CAPACITY (MOIST)
      SAVEVALUE   55,V53
      SPLIT       1,STRCB
*  SUBROUTINE FOR COMBINE-SWATH SEQUENCE
*  PICK UP LOSS AT .4 BU/ACRE
*      SWATHING LOSSES   .5230/ACRE
    9 FVARIABLE   X51*X60/100      SWATHING COST
      SAVEVALUE   1,V9
    2 FVARIABLE   X52-X4-K1        MOISTURE LEVEL
      SAVEVALUE   52,V2
      TEST L      X52,K14,SPL1
      SAVEVALUE   52,K14
SPL1  SPLIT       1,CCMBD
*  SUBROUTINE FOR COMBINEING SWATH MOIST
      TEST NE     X30,K1,ASS1
      SAVEVALUE   9+,K1            DAY COUNT
      TEST L      X52,X53,PEN1     DRYNESS
   24 FVARIABLE   4*X101/10        PICKUP LOSS
LOG1  SAVEVALUE   86,V24
      SAVEVALUE   87+,X86          ACC. LOSSES
   28 FVARIABLE   X5-X86           BU LEFT
      SAVEVALUE   5,V28
      LOGIC R     5
      TEST G      X52,K17,BUD1     DRYNESS
 42   FVARIABLE   X12+X55
      SAVEVALUE   12,V42           WET BU DONE
      SAVEVALUE   56,X52
1     FVARIABLE   X55*FN17/100     ACC. DRYING COSTS
      SAVEVALUE   8+,V1
      SAVEVALUE   58,X52
7     FVARIABLE   X55*FN18/100     ACC.CHEM. TREAT COSTS
      SAVEVALUE   10+,V7
      SAVEVALUE   5-,X55           BU LEFT
      TRANSFER    ,BUD5
    5 FVARIABLE   X15+X54
BUD1  SAVEVALUE   15,V5            DRY BU DONE
  3   FVARIABLE   X5-X54
      SAVEVALUE   5,V3             BU LEFT
BUD5  TEST G      X5,K0,LOOP1
TES1  TEST G      X5,K0,TERM1      BU LEFT
      TRANSFER    ,ASS1
LOOP1 TEST G      X52,K17,LOO1
```

```
   43   FVARIABLE  X12+X5
        SAVEVALUE  12,V43
  60    FVARIABLE  X5*FN17/100
        SAVEVALUE  8+,V60
  61    FVARIABLE  X5*FN18/100
        SAVEVALUE  10+,V61
        SAVEVALUE  5,0
        TRANSFER   ,TES1
   38   FVARIABLE  X15+X5
 LOC1   SAVEVALUE  15,V38
        SAVEVALUE  5,0
        TRANSFER   ,TES1
 PEN1   SAVEVALUE  7+,K1              BAD DAY COUNT
        GATE LR    5,TRAN1
        SAVEVALUE  90+,K1             BD AFTER COMB
 TRAN1 TRANSFER    ,TES1
 TERM1 SAVEVALUE   80,K1
        TRANSFER   ,ASS1
*   SUBROUTINE FOR    COMBINE-SWATH  DRY
 COMBD SAVEVALUE   20,0    DUMMY
        TEST NE    X81,K1,ASS1
        SAVEVALUE  11+,K1             DAY COUNT
        TEST L     X52,X61,PEN2       DRYNESS
   25   FVARIABLE  4*X101/10          PICKUP LOSSES
 LOG2   SAVEVALUE  88,V25
        SAVEVALUE  89+,X88            ACC. LOSSES
     29 FVARIABLE  X13-X88            BU LEFT
        SAVEVALUE  13,V29
     35 FVARIABLE  X64+X54            BU DONE
        SAVEVALUE  64,V35
        LOGIC R    6
   11   FVARIABLE  X13-X54
        SAVEVALUE  13,V11             BU LEFT
        TEST G     X13,K0,LOOP2
 TES2   TEST G     X13,K0,TERM2        BU  LEFT
        TRANSFER   ,ASS1
   39   FVARIABLE  X64+X13
 LOOP2 SAVEVALUE   64,V39
        SAVEVALUE  13,0
        TRANSFER   ,TES2
 PEN2   SAVEVALUE  14+,K1             BAD DAY COUNT
        GATE LR    6,TRAN2
        SAVEVALUE  91+,K1             BAD DAYS AFTER COMB.
 TRAN2 TRANSFER    ,TES2
 TERM2 SAVEVALUE   81,K1
        TRANSFER   ,ASS1
*   SUBROUTINE FOR STRAIGHT COMBINE
*   NO PICK UP LOSSES  --GREATER NATURAL LOSSES
 STRCB SAVEVALUE   20,0    DUMMY
     13 FVARIABLE  X40-X4             MOISTURE LEVEL
        SAVEVALUE  40,V13
        TEST L     X40,K14,SPL2
        SAVEVALUE  40,K14
 SPL2   SPLIT      1,STRW
*     SUBROUTINE FOR  STRAIGHT COMBINE DRY
        TEST NE    X82,K1,ASS1
        SAVEVALUE  44+,K1             DAY COUNT
```

```
         TEST L      X40,X62,PEN3      DRYNESS
   26    FVARIABLE   93*X101/100       NATURAL,REEL&CUTTERBAR LOSSES
 LOG3    SAVEVALUE   94,V26                 FROM 35%
         SAVEVALUE   95+,X94           ACC. LOSSES
    37   FVARIABLE   X41-X94
         SAVEVALUE   41,V37            BU LEFT
         LOGIC R     7
    36   FVARIABLE   X65+X54           BU DONE
         SAVEVALUE   65,V36
    15   FVARIABLE   X41-X54
         SAVEVALUE   41,V15            BU LEFT
         SAVEVALUE   103+,V33          ACRES DONE
  51     FVARIABLE   (X51-X103)*1666/10000   NATURAL LOSS
         SAVEVALUE   41-,V51                AFTER 14%
         TEST G      X41,K0,LOOP3
 TES3    TEST G      X41,KC,TERM3        BU LEFT
         TRANSFER    ,ASS1
   40    FVARIABLE   X65+X41
 LOOP3   SAVEVALUE   65,V40
         SAVEVALUE   41,0
         TRANSFER    ,TES3
 PEN3    SAVEVALUE   50+,K1            BAD DAY COUNT
         GATE LR     7,TRAN3
         SAVEVALUE   92+,K1            BAD DAY COUNT AFTER COMB.
 TRAN3   TRANSFER    ,TES3
 TERM3   SAVEVALUE   82,K1
         TRANSFER    ,ASS1
*     SUBROUTINE FOR STRAIGHT COMBINE MOIST
 STRW    SAVEVALUE   20,0       DUMMY
         TEST NE     X83,K1,ASS1
         SAVEVALUE   46+,K1            DAY COUNT
         TEST L      X40,X63,PEN4      DRYNESS
 27      FVARIABLE   58*X101/100       REEL & CUTTERBAR PLUS
  LOG4   SAVEVALUE   96,V27                 NATURAL LOSSES
         SAVEVALUE   97+,X96           ACC. LOSSES
    31   FVARIABLE   X48-X96
         SAVEVALUE   48,V31            BU LEFT
         LOGIC R     8
         TEST G      X40,K17,BUD2      DRYNESS
  44     FVARIABLE   X42+X55
         SAVEVALUE   42,V44            WET BU DONE
         SAVEVALUE   56,X40
 20      FVARIABLE   X55*FN17/100      ACC. DRYING COSTS
         SAVEVALUE   43+,V20
         SAVEVALUE   58,X40
 22      FVARIABLE   X55*FN18/100      ACC. CHEM. TREAT COSTS
         SAVEVALUE   45+,V22
         SAVEVALUE   48-,X55           BU LEFT
         SAVEVALUE   102+,V54
         TRANSFER    ,BUD6
    17   FVARIABLE   X47+X54
 BUD2    SAVEVALUE   47,V17            BU DONE
    18   FVARIABLE   X48-X54
         SAVEVALUE   48,V18
         SAVEVALUE   102+,V33          ACRES DONE
  50     FVARIABLE   (X51-X102)*1666/10000   NATURAL LOSS
 BUD6    SAVEVALUE   48-,V50                AFTER 14%
```

```
       TEST G       X48,KC,LOOP4
TES4   TEST G       X48,KC,TERM4      BU LEFT
       TRANSFER     ,ASS1
LOOP4  TEST G       X40,K17,LOC4
 45    FVARIABLE    X42+X48
       SAVEVALUE    42,V45
 62    FVARIABLE    X48*FN17/100
       SAVEVALUE    43+,V62
 63    FVARIABLE    X48*FN18/100
       SAVEVALUE    45+,V63
       SAVEVALUE    48,0
       TRANSFER     ,TES4
  46   FVARIABLE    X47+X48
LOC4   SAVEVALUE    47,V46
       SAVEVALUE    48,0
       TRANSFER     ,TES4
PEN4   SAVEVALUE    32+,K1              BAD DAY COUNT
       GATE LR      8,TRAN4
       SAVEVALUE    93+,K1              BAD DAYS AFTER COMB
TRAN4  TRANSFER     ,TES4
TERM4  SAVEVALUE    83,K1
ASS1   ASSEMBLE     4
       TEST L       X71,X72,ASS2
       TEST E       X80,K1,DAYC
       TEST E       X81,K1,DAYC
       TEST E       X82,K1,DAYC
       TEST E       X83,K0,ASS2
 DAYC  SAVEVALUE    71+,K1        DAY COUNT
       TRANSFER     ,START
ASS2   SAVEVALUE    7-,X90
       SAVEVALUE    14-,X91
       SAVEVALUE    50-,X92
       SAVEVALUE    32-,X93
       TABULATE     1
       TABULATE     2
       TABULATE     3
       TABULATE     4
       TABULATE     5
       TABULATE     6
       TABULATE     7
       TABULATE     8
       TABULATE     9
       TABULATE     10
       TABULATE     11
       TABULATE     12
       TABULATE     13
       TABULATE     14
       TABULATE     15
       TABULATE     16
       TABULATE     17
       TABULATE     18
       TABULATE     19
       TABULATE     20
       TABULATE     21
       TABULATE     22
       TABULATE     23
       TABULATE     24
```

```
        TABULATE    25
        TABULATE    26
        TABULATE    27
        TABULATE    28
        TABULATE    29
        TABULATE    30
     1  TABLE       X9,0,1,50          DAYS
     2  TABLE       X7,0,1,50          DAYS BEFORE
     3  TABLE       X90,0,1,40         BAD DAYS
     4  TABLE       X5,C,500,100       BU LEFT
     5  TABLE       X87,C,100,100      BU LOST
     6  TABLE       X15,3500,500,50     TOTAL BU
     7  TABLE       X12,C,100,200      WET BU
     8  TABLE       X11,0,1,50         DAYS
     9  TABLE       X14,0,1,50         DAYS BEFORE
    10  TABLE       X91,0,1,40         BAD DAYS
    11  TABLE       X13,0,500,100      BU LEFT
    12  TABLE       X39,C,100,100      BU LOST
    13  TABLE       X64,3500,500,50     TOTAL BU
    14  TABLE       X44,0,1,50         DAYS
    15  TABLE       X50,0,1,50         DAYS BEFORE
    16  TABLE       X92,0,1,40         BAD DAYS
    17  TABLE       X41,C,500,100      BU LEFT
    18  TABLE       X95,0,100,100      BU LOST
    19  TABLE       X65,3500,500,50     TOTAL BU
    20  TABLE       X46,C,1,50         DAYS
    21  TABLE       X32,0,1,50         DAYS BEFORE
    22  TABLE       X93,0,1,40         BAD DAYS
    23  TABLE       X48,C,500,100      BU LEFT
    24  TABLE       X97,C,100,100      BU LOST
    25  TABLE       X47,3500,500,50     TOTAL BU
    26  TABLE       X42,C,100,200      WET BU
  27    TABLE       X8,C,100,200       $ DRY CSM
  28    TABLE       X10,C,100,200      $ CHEM CSM
  29    TABLE       X43,0,100,200      $ DRY SCM
  30    TABLE       X45,C,100,200      $ CHEM SCM
        TERMINATE   1
        START       100
        END
```

TABLE 21

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
100	6.769	5.460	677.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-1.239
1	1	.99	.9	99.0	.147	-1.056
2	10	9.99	10.9	89.0	.295	-.873
3	18	17.99	28.9	71.0	.443	-.690
4	11	10.99	39.9	60.0	.590	-.507
5	13	12.99	52.9	47.0	.738	-.324
6	5	4.99	57.9	42.0	.886	-.141
7	10	9.99	67.9	32.0	1.033	.042
8	8	7.99	75.9	24.0	1.181	.225
9	6	5.99	81.9	18.0	1.329	.408
10	7	6.99	88.9	11.0	1.477	.591
11	2	1.99	90.9	9.0	1.624	.774
12	0	.00	90.9	9.0	1.772	.957
13	1	.99	91.9	8.0	1.920	1.140
14	1	.99	92.9	7.0	2.067	1.323
15	1	.99	93.9	6.0	2.215	1.507
16	2	1.99	95.9	4.0	2.363	1.690
17	0	.00	95.9	4.0	2.511	1.873
18	0	.00	95.9	4.0	2.658	2.056
19	1	.99	96.9	3.0	2.806	2.239
20	0	.00	96.9	3.0	2.954	2.422
21	0	.00	96.9	3.0	3.101	2.605
22	0	.00	96.9	3.0	3.249	2.788
23	0	.00	96.9	3.0	3.397	2.972
24	1	.99	97.9	2.0	3.545	3.155
25	0	.00	97.9	2.0	3.692	3.338
26	0	.00	97.9	2.0	3.840	3.521
27	0	.00	97.9	2.0	3.988	3.704
28	0	.00	97.9	2.0	4.135	3.887
29	0	.00	97.9	2.0	4.283	4.070
30	0	.00	97.9	2.0	4.431	4.253
31	1	.99	98.9	1.0	4.579	4.436
32	0	.00	98.9	1.0	4.726	4.620
33	0	.00	98.9	1.0	4.874	4.803
34	0	.00	98.9	1.0	5.022	4.986
35	1	.99	100.0	.0	5.169	5.169

REMAINING FREQUENCIES ARE ALL ZERO

District: Beaverlodge — Combine Capacity (lbs/min): 95 — Acres: 280

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	12.80	6.12	19.84	9.66	24.23	12.16	14.20	7.51
Maturation Days	5.08	4.00	8.33	5.07	11.69	8.17	6.81	6.38
Bad Days	.25	.77	2.52	3.86	4.12	6.89	.48	1.61
% Completion	100		96		87		99	
Bushels Left	-		8521 in 4 yrs.		35,711 in 13 yrs.		8960 in 1 yr.	
Grain Loss	185	12	200	13	243	49	131	21
Bu. Harvested Dry	2620	1789	5650	1491	5159	1519	1789	1578
Bu. Harvested Moist	3130	1523	-		-		3801	1735
Cost of Drying	368.	224.					443.	250.
Cost of Chemical	195.	119.					229.	132.

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 135 | Acres: 280

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.13	5.10	16.16	7.71	20.08	10.5	11.73	6.00
Maturation Days	4.83	3.40	8.05	3.56	10.81	6.14	6.19	4.27
Bad Days	1.59	.58	1.74	3.27	3.10	5.85	.559	1.44
% Completion	100		99		96		99	
Bushels Left	-		4185 in 1 year		14,987 in 4 years		1093 in 1 year	
Grain Loss	187	11	205	12	268	45	137	23
Bu. Harvested Dry	1789	1791	5688	1492	5402	1558	1321	1560
Bu. Harvested Moist	3958	1771	-		-		4389	1694
Cost of Drying	510	286					560	298
Cost of Chemical	270	152					296	158

* Standard Deviation

District: Beaverlodge — Combine Capacity (lbs/min): 155 — Acres: 280

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	9.97	4.68	15.70	7.32	19.60	10.05	11.39	5.37
Maturation Days	5.21	3.10	8.31	3.77	10.97	5.73	6.69	4.05
Bad Days	.169	.71	1.73	3.33	2.85	5.19	.229	.76
% Completion	100		99		95		100	
Bushels Left	-		3933 in 1 year		14,207 in 5 years		-	
Grain Loss	187	15	206	15	272	45	140	20
Bu. Harvested Dry	1713	1878	5689	1508	5413	1468	1286	1750
Bu. Harvested Moist	4035	1740	-		-		4523	1810
Cost of Drying	496	273					587	300
Cost of Chemical	263	144					311	159

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 195 | Acres: 280

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	8.23	3.05	13.18	5.23	16.48	7.09	9.85	4.70
Maturation Days	4.65	2.60	7.76	3.19	10.52	5.82	5.89	3.63
Bad Days	.129	.54	.92	2.53	1.47	3.24	.48	2.32
% Completion	100		99		99		100	
Bushels Left	-		418 bu. in 1 yr		7560 in 1 year		-	
Grain Loss	187	14	215	16	283	46	144	26
Bu. Harvested Dry	1284	1699	5716	1532	5505	1600	981	1470
Bu. Harvested Moist	4464	1835	-		-		4771	1735
Cost of Drying	589	304					642	307
Cost of Chemical	312	161					340	163

* Standard Deviation

District: Beaverlodge Combine Capacity (lbs/min): 240 Acres: 280

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	7.57	3.04	12.36	4.85	15.73	6.95	9.10	5.07
Maturation Days	4.53	2.28	7.97	3.69	10.67	6.14	5.91	3.85
Bad Days	.179	1.01	.589	1.15	1.27	2.3	.389	2.38
% Completion	100		100		99		100	
Bushels Left	-	-	-		8960 in 1 year		-	
Grain Loss	193	23	220	22	300	60	147	28
Bu. Harvested Dry	1014	1596	5715	1540	5494	1592	616	1126
Bu. Harvested Moist	4728	1771	-		-		5148	1508
Cost of Drying	630	309					689	274
Cost of Chemical	334	164					366	145

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 260 | Acres: 280

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	7.44	3.52	11.89	5.00	15.18	7.37	8.96	5.59
Maturation Days	4.70	2.92	8.05	3.85	10.63	6.01	6.25	5.12
Bad Days	.129	.73	.54	1.45	1.19	2.98	.149	.46
% Completion	100		100		99		100	
Bushels Left	-		-		8690 in 1 year		--	
Grain Loss	194	22	220	19	330	62	148	32
Bu. Harvested Dry	741	1411	5715	1534	5502	1591	630	1346
Bu. Harvested Moist	5000	1526	-		-		5139	1519
Cost of Drying	671	276					758	272
Cost of Chemical	356	146					402	144

* Standard Deviation

District: Beaverlodge   Combine Capacity (lbs/min): 95   Acres: 450

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	16.98	7.68	26.77	11.18	30.29	11.76	18.02	8.60
Maturation Days	4.70	2.86	8.12	4.30	11.09	7.62	6.30	5.38
Bad Days	.47	1.69	5.16	5.75	7.11	8.02	.75	1.77
% Completion	98		88		80		97	
Bushels Left	1991 in 2 years		40,203 in 12 yrs		92,548 in 20 years		12,570 in 3 years	
Grain Loss	294	15	312	25	356	89	205	27
Bu. Harvested Dry	4671	2664	8825	2298	7798	2494	3510	2551
Bu. Harvested Moist	4553	2583	-		-		5334	2464
Cost of Drying	501	339					603	349
Cost of Chemical	265	179					319	185

* Standard Deviation

District: Beaverlodge   Combine Capacity (lbs/min): 135   Acres: 450

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	13.32	6.15	22.22	10.56	26.31	12.64	14.70	6.94
Maturation Days	4.75	2.73	8.02	3.44	11.98	81.20	6.20	3.93
Bad Days	.33	1.43	4.07	5.24	4.92	6.91	.67	1.76
% Completion	100		95		82		99	
Bushels Left	-		12,605 in 5 yrs.		60,268 in 18 yrs		2418 in 1 yr.	
Grain Loss	298	14	323	18	387	80	215	26
Bu. Harvested Dry	4040	2856	9090	2367	8219	2436	2999	2767
Bu. Harvested Moist	5200	2308	-		-		6063	2711
Cost of Drying	594	340					732	422
Cost of Chemical	315	180					388	244

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 155 | Acres: 450

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	11.68	5.20	19.24	8.86	24.29	11.38	12.93	5.70
Maturation Days	4.85	4.27	8.01	4.37	10.99	6.48	6.10	5.01
Bad Days	.20	.80	2.95	4.65	5.10	7.12	.56	1.59
% Completion	99		97		90		99	
Bushels Left	9913 in 1 year		16,904 in 3 yr.		41,748 in 10 yr.		13,500 in 1 year	
Grain Loss	297	21	324	23	403	68	211	30
Bu. Harvested Dry	3718	2698	9046	2531	8448	2421	2550	2516
Bu. Harvested Moist	5425	2239	-		-		6463	2836
Cost of Drying	621	331					748	392
Cost of Chemical	329	175					397	208

* Standard Deviation

District: Beaverlodge	Combine Capacity (lbs/min): 195						Acres: 450	
	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.81	5.00	17.16	8.66	21.20	11.0	12.85	7.68
Maturation Days	4.70	2.89	7.98	3.84	11.69	8.44	6.52	5.88
Bad Days	.24	.75	1.96	3.66	2.68	4.61	.68	2.11
% Completion	100		99		92		99	
Bushels Left	-		2554 in 1 year		45,206 in 8 yrs.		11,700 in 1 year	
Grain Loss	303	18	332	17	417	84	220	36
Bu. Harvested Dry	3463	2842	9172	2435	8454	2536	2576	2960
Bu. Harvested Moist	5772	2350	-		-		6472	3079
Cost of Drying	717	362					783	431
Cost of Chemical	380	192					416	228

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 240 | Acres: 450

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	9.15	3.80	14.90	6.12	18.17	8.39	10.50	4.68
Maturation Days	4.5	2.52	7.76	3.27	9.85	4.34	5.80	3.41
Bad Days	.167	.67	1.54	2.69	2.79	5.02	.30	1.09
% Completion	100		100		99		100	
Bushels Left	-		-		1781 in 1 yr.		-	
Grain Loss	304	24	336	16	440	43	299	32
Bu. Harvested Dry	2712	3284	9203	2464	8919	2383	2029	2696
Bu. Harvested Moist	6523	2854	-		-		7182	2514
Cost of Drying	859	493					919	425
Cost of Chemical	455	262					488	226

* Standard Deviation

District: Beaverlodge — Combine Capacity (lbs/min): 260 — Acres: 450

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	9.02	3.52	14.99	6.39	18.20	8.24	10.45	4.44
Maturation Days	4.75	2.84	8.12	3.42	10.65	5.74	6.11	3.90
Bad Days	.18	.67	1.54	3.08	2.24	3.82	.32	.98
% Completion	100		100		99		100	
Bushels Left	-		-		11,346 in 1 yr.		-	
Grain Loss	302	22	337	18	443	62	225	38
Bu. Harvested Dry	2150	2813	9202	2464	8834	2460	16.18	2328
Bu. Harvested Moist	7087	2946	-		-		7608	2912
Cost of Drying	898	490					1032	479
Cost of Chemical	476	260						

* Standard Deviation

District: Beaverlodge　　Combine Capacity (lbs/min): 95　　Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	31.36	9.63	41.23	8.45	42.0	8.21	31.00	9.90
Maturation Days	5.01	3.78	8.48	5.12	12.00	8.42	6.99	5.88
Bad Days	.98	1.94	9.73	6.62	11.52	7.47	2.09	4.67
% Completion	86		42		40		80	
Bushels Left	122,543 in 14 yrs.		527,509 in 58 yr.		639,673 in 60 years		155,786 in 20 yrs.	
Grain Loss	638	53	616	99	572	245	407	88
Bu. Harvested Dry	11,585	4064	15,308	4608	12,291	4816	8937	4079
Bu. Harvested Moist	7750	4304	-		-		8338	4144
Cost of Drying	775	473					885	539
Cost of Chemical	410	250					468	286

* Standard Deviation

District: Beaverlodge Combine Capacity (lbs/min): 135 Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	23.21	10.09	33.98	11.41	36.03	11.16	24.5	10.6
Maturation Days	4.54	3.09	8.42	4.94	11.43	7.61	6.4	6.30
Bad Days	.67	1.32	7.47	6.46	9.56	8.24	1.87	4.48
% Completion	93		66		58		91	
Bushels Left	45,996 in 7 yrs.		332,076 in 34 yrs.		473,470 in 42 yrs.		91,479 in 9 years	
Grain Loss	651	37	656	88	666	246	243	84
Bu. Harvested Dry	10572	4816	17222	4736	14338	5136	8255	3809
Bu. Harvested Moist	9516	4800	-		-		10258	5200
Cost of Drying	1032	600					1099	582
Cost of Chemical	547	318					582	309

* Standard Deviation

District: Beaverlodge Combine Capacity (lbs/min): 155 Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	23.23	10.17	33.02	11.41	35.25	10.80	23.81	10.19
Maturation Days	5.04	2.69	8.14	3.86	11.81	8.06	6.85	4.98
Bad Days	.58	1.82	7.39	6.74	8.77	7.84	1.69	4.47
% Completion	95		71		67		90	
Bushels Left	23594 in 5 years		280779 in 29 yrs.		388683 in 33 yrs		88426 in 10 years	
Grain Loss	659	33	664	85	708	246	442	80
Bu. Harvested Dry	11656	5040	17727	5152	15246	5840	8746	4736
Bu. Harvested Moist	8648	4688	-		-		9875	4464
Cost of Drying	906	569					1080	600
Cost of Chemical	479	301					572	318

* Standard Deviation

District: Beaverlodge	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Combine Capacity (lbs/min): 195								
Acres: 1000								
Total Days	18.43	8.07	27.64	11.39	30.88	11.65	19.71	9.46
Maturation Days	5.26	4.04	8.62	4.60	11.30	6.63	6.67	5.53
Bad Days	.519	1.49	5.03	5.95	7.21	7.60	1.2	2.99
% Completion	98		82		74		95	
Bushels Left	26535 in 2 years		183219 in 18 yrs.		295667 in 26 years		49215 in 5 years	
Grain Loss	158	8	172	9	221	23	119	14
Bu. Harvested Dry	10622	5152	18678	4864	16384	5152	7855	5440
Bu. Harvested Moist	9648	5184	-		-		11495	5824
Cost of Drying	1024	677					1320	748
Cost of Chemical	543	359					700	397

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 240 | Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	15.99	7.70	25.28	11.65	28.89	12.52	17.68	9.33
Maturation Days	4.56	2.59	8.21	4.25	11.27	7.87	6.24	4.43
Bad Days	.39	1.33	4.68	5.54	6.54	7.45	1.21	3.38
% Completion	99		87		79		96	
Bushels Left	1563 in 1 year		109718 in 13 years		223877 in 21 yrs.		200071 in 4 years	
Grain Loss	666	36	703	58	807	213	464	60
Bu. Harvested Dry	9934	5824	19399	5216	17209	5664	7464	5584
Bu. Harvested Moist	10582	5520	-		-		12307	5824
Cost of Drying	1180	737					1429	814
Cost of Chemical	625	391					758	432

* Standard Deviation

District: Beaverlodge | Combine Capacity (lbs/min): 260 | Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	14.98	6.58	23.74	11.18	26.49	11.74	16.63	7.97
Maturation Days	4.91	2.72	8.26	3.74	10.82	6.43	6.39	4.03
Bad Days	.33	.83	4.11	5.92	5.50	7.67	.96	3.44
% Completion	99		91		85		97	
Bushels Left	1119 in 1 year		58551 in 9 yrs.		154731 in 15 years		11570 in 3 years	
Grain Loss	669	32	714	46	848	175	478	58
Bu. Harvested Dry	9831	6144	19900	52006	17970	5264	8189	6160
Bu. Harvested Moist	10687	5888	-		-		11755	5872
Cost of Drying	1218	806					1383	851
Cost of Chemical	646	428					734	452

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 95 | Acres: 240

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	12.17	5.38	18.47	8.40	21.53	10.68	13.65	6.24
Maturation Days	4.29	2.37	7.60	3.25	9.66	4.57	5.79	3.70
Bad Days	.16	.54	1.85	3.18	2.90	5.71	.31	.94
% Completion	100		100		98		100	
Bushels Left	-		-		2567 in 2 years		-	
Grain Loss	158	8	172	9	221	23	119	14
Bu. Harvested Dry	3024	2353	6679	2138	6449	2043	2599	2231
Bu. Harvested Moist	3668	1748	-		-		4016	1926
Cost of Drying	424	245					464	270
Cost of Chemical	224	130					245	143

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 135 | Acres: 240

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	9.35	3.91	14.29	6.42	16.76	7.66	10.37	4.36
Maturation Days	3.86	2.34	6.75	2.87	8.69	4.21	4.84	3.10
Bad Days	.07	.32	1.22	2.51	1.77	3.19	.23	.85
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	163	10	177	12	231	25	124	19
Bu. Harvested Dry	2521	2490	6674	2140	6250	2095	2060	2228
Bu. Harvested Moist	4166	2031	-		-		4597	1994
Cost of Drying	515	317					574	298
Cost of Chemical	273	168					304	158

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 155 | Acres: 240

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	8.92	3.80	14.15	5.62	16.31	7.32	10.51	5.02
Maturation Days	4.12	2.07	7.47	3.12	9.15	4.51	5.49	3.33
Bad Days	.08	.27	.92	1.98	1.49	2.74	.39	1.23
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	162	13	179	11	236	28	123	18.5
Bu. Harvested Dry	2060	2300	6672	2139	6529	2106	1753	2215
Bu. Harvested Moist	4629	1977	-		-		4917	2184
Cost of Drying	594	314					654	344
Cost of Chemical	315	166					347	182

* Standard Deviation

District: Lacombe — Combine Capacity (lbs/min): 195 — Acres: 240

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	8.22	3.42	13.05	5.66	15.44	7.56	9.79	4.97
Maturation Days	4.27	2.54	7.64	3.55	9.92	5.67	5.79	4.16
Bad Days	.25	1.29	.72	1.71	.84	1.83	.28	.94
% Completion	100		100		99		100	
Bushels Left	-		-		1355 in 1 year		-	
Grain Loss	165	17	183	16	249	38	127	23
Bu. Harvested Dry	1383	1834	6668	2140	6529	2099	1176	1952
Bu. Harvested Moist	5303	2191	-		-		5510	2144
Cost of Drying	683	346					740	330
Cost of Chemical	362	183					393	175

* Standard Deviation

District: Lacombe   Combine Capacity (lbs/min): 240   Acres: 240

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	7.42	3.37	11.52	4.12	13.75	5.50	8.77	4.50
Maturation Days	4.23	2.68	7.38	3.57	9.02	4.62	5.56	4.18
Bad Days	.21	.71	.35	.90	.98	1.88	.20	.70
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	166	16	190	21	262	49	132	27
Bu. Harvested Dry	1146	1855	6661	2145	6548	2137	1128	1790
Bu. Harvested Moist	5539	2292	-		-		5569	2136
Cost of Drying	740	412					766	321
Cost of Chemical	393	218					407	170

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 260 | Acres: 240

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	7.58	3.43	11.28	4.58	13.70	6.08	8.66	4.29
Maturation Days	4.58	3.03	7.40	3.32	9.34	4.48	5.74	3.87
Bad Days	.13	.48	.47	1.53	.78	1.9	.14	.59
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	170	19	189	20	270	57	133	31
Bu. Harvested Dry	1457	2142	6662	2145	6545	2134	946	1778
Bu. Harvested Moist	5223	2151	-		-		5753	2047
Cost of Drying.	709	380					777	288
Cost of Chemical	376	202					412	153

* Standard Deviation

District: Lacombe   Combine Capacity (lbs/min): 95   Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	19.71	9.80	29.75	14.83	33.66	16.44	20.56	9.57
Maturation Days	4.26	2.57	7.58	3.39	9.65	4.82	5.71	3.74
Bad Days	.179	.49	4.92	6.74	7.90	10.05	.39	1.08
% Completion	99		92		89		99	
Bushels Left	965 in 1 year		27531 in 8 yrs.		53421 in 11 years		1857 in 1 year	
Grain Loss	277	11	291	18	349	54	196	17
Bu. Harvested Dry	6783	3795	11423	3488	10536	3307	5691	3486
Bu. Harvested Moist	4920	2480	-		-		5612	2644
Cost of Drying	537	330					609	335
Cost of Chemical	284	175					322	177

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 135 | Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	14.20	5.88	20.53	9.76	24.07	12.16	15.30	7.01
Maturation Days	4.75	2.78	7.71	3.37	9.73	4.33	6.06	3.97
Bad Days	.15	.50	1.99	3.48	3.77	5.74	.20	.71
% Completion	100		100		97		100	
Bushels Left	-		-		-		-	
Grain Loss	284	13	302	12	379	27	209	19
Bu. Harvested Dry	6373	3882	11688	3739	11213	3536	5520	3879
Bu. Harvested Moist	5332	2869	-		-		6000	2803
Cost of Drying	604	402					684	368
Cost of Chemical	302	213					363	195

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 155 | Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	13.05	6.20	19.85	10.30	22.88	11.55	14.24	6.87
Maturation Days	4.34	2.54	7.38	2.98	9.65	4.46	5.37	3.26
Bad Days	.09	.32	2.30	4.39	3.31	5.64	.50	1.75
% Completion	100		99		98		100	
Bushels Left	-		876 in 1 year		8980 in 2 years		-	
Grain Loss	281	16	304	12	383	34	208	25
Bu. Harvested Dry	5512	4128	11678	3731	11201	3558	4522	4022
Bu. Harvested Moist	6197	3069	-		-		7024	3399
Cost of Drying	706	419					837	452
Cost of Chemical	374	222					444	239

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 195 | Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	11.28	5.34	16.56	6.96	19.58	9.35	12.59	5.88
Maturation Days	4.36	2.55	7.63	3.32	9.76	4.50	5.58	3.61
Bad Days	.28	1.05	1.19	1.76	2.03	4.41	.48	1.54
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	284	18	309	16	398	37	212	25
Bu. Harvested Dry	4696	4112	11681	3742	11362	3645	4032	4128
Bu. Harvested Moist	7010	3327	-		-		7576	3757
Cost of Drying	843	494					914	516
Cost of Chemical	447	262					485	274

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 240 | Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.0	3.91	14.41	5.51	17.62	9.23	11.06	4.52
Maturation Days	4.5	2.74	7.20	3.19	9.37	4.89	5.51	3.54
Bad Days	.09	.35	.88	1.97	1.82	4.60	.26	1.05
% Completion	100		100		99		100	
Bushels Left	-		-		4019 in 1 year		-	
Grain Loss	288	19	313	20	415	52	217	26
Bu. Harvested Dry	4673	4320	11677	3744	11360	3650	3668	4020
Bu. Harvested Moist	7029	3394	-		-		7981	3781
Cost of Drying	848	530					1011	558
Cost of Chemical	450	281					537	296

* Standard Deviation

District: Lacombe — Combine Capacity (lbs/min): 260 — Acres: 420

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	9.04	3.41	13.73	4.48	16.39	6.23	9.99	4.08
Maturation Days	4.17	2.12	7.19	2.86	9.14	4.11	5.16	2.89
Bad Days	.13	.50	.73	1.72	1.48	2.91	.20	.83
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	287	20	315	19	412	42	218	32
Bu. Harvested Dry	3796	3680	11675	3742	11424	3687	2855	3749
Bu. Harvested Moist	7906	3844	-		-		8818	3883
Cost of Drying	960	570					1154	634
Cost of Chemical	590	303					612	337

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 95 | Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	39.82	17.69	49.34	17.8	51.16	17.68	38.67	17.5
Maturation Days	4.68	2.93	7.75	3.43	9.91	5.12	6.19	3.96
Bad Days	1.06	2.71	11.20	9.24	15.10	11.27	2.07	4.64
% Completion	80		57		50		85	
Bushels Left	183383 in 20 yrs		625065 in 43 yrs		653994 in 50 years		126659 in 15 years	
Grain Loss	644	55	629	99	638	227	427	78
Bu. Harvested Dry	17492	6336	21670	7344	18680	6832	14257	5872
Bu. Harvested Moist	8579	4848	-		-		9868	5216
Cost of Drying	827	557					1011	591
Cost of Chemical	437	295					534	313

* Standard Deviation

District: Lacombe | Combine Capacity (lbs/min): 135 | Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	29.56	14.85	40.75	17.62	43.39	17.62	29.13	14.18
Maturation Days	4.11	2.07	7.35	3.01	9.37	3.95	5.31	3.13
Bad Days	.65	1.93	8.16	8.23	11.89	11.28	1.43	4.18
% Completion	95		76		70		95	
Bushels Left	52535 in 5 years		296319 in 24 yrs		371274 in 30 yrs		40512 in 5 years	
Grain Loss	662	35	673	73	745	190	459	54
Bu. Harvested Dry	17597	6720	24913	7744	22020	7344	14154	6272
Bu. Harvested Moist	9764	4816	-		-		11659	5504
Cost of Drying	962	603					1165	628
Cost of Chemical	509	319					617	333

* Standard Deviation

District: Lacombe Combine Capacity (lbs/min): 155 Acres: 1000

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	26.22	13.42	37.88	18.6	40.72	18.75	26.76	12.92
Maturation Days	4.5	2.18	7.92	2.93	10.33	4.48	5.80	2.96
Bad Days	.35	1.28	7.25	8.58	10.60	10.38	1.33	3.42
% Completion	99		78		75		99	
Bushels Left	3998 in 1 year		170223 in 22 yrs		243626 in 25 years		4029 in 1 year	
Grain Loss	669	20	688	50	786	151	473	42
Bu. Harvested Dry	17801	7680	26159	7952	23492	7504	14769	7040
Bu. Harvested Moist	10039	4480	-		-		11691	5936
Cost of Drying	1031	532					1233	709
Cost of Chemical	546	282					653	375

* Standard Deviation

District: Lacombe　　Combine Capacity (lbs/min): 195　　Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	20.56	9.13	31.59	15.75	35.23	17.44	21.01	8.71
Maturation Days	4.20	2.30	7.31	2.75	9.50	4.23	5.41	3.04
Bad Days	.16	.44	5.74	7.30	8.60	10.61	.43	1.07
% Completion	100		91		85		100	
Bushels Left	-		50646 in 9 years		124571 in 15 yrs		-	
Grain Loss	672	18	706	29	837	115	483	37
Bu. Harvested Dry	16606	8352	27336	8592	25012	8032	13650	7424
B. Harvested Moist	11271	5184	-		-		13235	6544
Cost of Drying	1173	629					1456	838
Cost of Chemical	622	333					772	445

* Standard Deviation

District: Lacombe | Combine lapacity (lbs/min): 240 | Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	16.79	7.37	25.93	13.0	30.0	16.0	17.77	7.87
Maturation Days	4.29	2.27	7.54	2.91	9.79	4.48	5.57	3.23
Bad Days	.15	.59	3.82	5.62	6.36	8.52	.38	1.22
% Completion	100		98		90		100	
Bushels Left	-		16616 in 2 yrs		57231 in 10 yrs		-	
Grain Loss	674	23	720	30	885	87	489	41
Bu. Harvested Dry	15098	8576	27663	8736	25978	8064	12147	8064
Bu. Harvested Moist	12776	6032	-		-		15053	7888
Cost of Drying	1359	777					1658	966
Cost of Chemical	721	412					880	513

* Standard Deviation

District: Lacombe Combine Capacity (lbs/min): 260 Acres: 1000

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	16.12	6.97	24.26	11.64	28.28	13.71	17.36	7.58
Maturation Days	4.16	2.04	7.63	2.76	9.95	4.12	5.58	3.12
Bad Days	.27	.88	3.12	4.78	5.24	7.6	.59	1.47
% Completion	100		98		94		100	
Bushels Left	-		22307 in 2 yrs		57865 in 6 yrs		-	
Grain Loss	673	23	719	28	888	94	492	38
Bu. Harvested Dry	14624	8288	27607	8784	26049	8304	12354	8032
Bu. Harvested Moist	13252	6352	-		-		14895	7168
Cost of Drying	1477	836					1693	946
Cost of Chemical	784	444					898	502

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 95 | Acres: 260

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.49	4.06	16.54	7.39	19.51	10.5	11.89	5.24
Maturation Days	3.99	2.12	7.47	3.28	9.08	4.41	5.33	3.51
Bad Days	.17	.64	1.43	2.69	2.86	6.09	.34	1.1
% Completion	100		100		99		100	
Bushels Left	-		-		2009 in 1 year		-	
Grain Loss	173	10	188	10	241	27	127	16
Bu. Harvested Dry	2076	1806	5463	1473	5250	1403	1829	1768
Bu. Harvested Moist	3402	1641		1	-		3595	1597
Cost of Drying	410	235					447	242
Cost of Chemical	217	125					237	128

* Standard Deviation

District: Lethbridge | Combining Capacity (lbs/min): 125 | Acres: 260

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	8.73	3.29	13.57	4.89	16.43	7.53	10.08	4.16
Maturation Days	4.25	2.01	7.31	3.01	9.59	5.33	5.34	3.07
Bad Days	.13	.54	.82	1.80	1.32	2.4	.48	1.69
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	175	12	196	13	257	30	134	23
Bu. Harvested Dry	1701	1764	5456	1476	5304	1444	1099	1523
Bu. Harvested Moist	3774	1698	-		-		4364	1716
Cost of Drying	476	268					579	294
Cost of Chemical	252	142					307	156

* Standard Deviation

District: Lethbridge — Combining Capacity (lbs/min): 155 — Acres: 260

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	7.98	3.01	12.49	5.0	14.91	7.06	9.38	4.40
Maturation Days	4.21	2.43	7.28	3.13	9.37	5.09	5.35	3.51
Bad Days	.11	.40	.65	1.54	1.05	2.43	.35	1.12
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	178	15	201	18	257	29	139	23
Bu. Harvested Dry	1377	1730	5451	1477	5327	1446	1164	1671
Bu. Harvested Moist	4096	1713	-		-		4308	1773
Cost of Drying	526	291					583	280
Cost of Chemical	279	155					309	149

* Standard Deviation

District: Lethbridge | Combining Capacity (lbs/min): 195 | Acres: 260

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	7.85	3.20	12.11	3.92	14.42	5.9	9.09	4.09
Maturation Days	4.40	2.5	7.44	3.18	9.26	4.27	5.70	3.71
Bad Days	.14	.45	.53	1.46	1.17	2.96	.09	.47
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	181	18	200	22	263	31	140	26
Bu. Harvested Dry	1144	1649	5451	1478	5333	1453	884	1487
Bu. Harvested Moist	4326	1625	-		-		4595	1623
Cost of Drying	563	281					655	285
Cost of Chemical	299	149					347	151

* Standard Deviation

District: Lethbridge		Combining Capacity (lbs/min): 240						Acres: 260
	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	7.15	2.92	10.96	3.99	13.36	5.9	8.39	3.89
Maturation Days	4.48	2.34	7.43	3.03	9.46	4.59	5.74	3.47
Bad Days	.08	.34	.33	1.29	.63	1.88	.09	.43
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	186	28	204	21	290	60	146	35
Bu. Harvested Dry	759	1405	5447	1477	5327	1473	577	1385
Bu. Harvested Moist	4706	1613	-		-		4914	1598
Cost of Drying	639	325					694	287
Cost of Chemical	339	173					368	152

* Standard Deviation

District: Lethbridge | Combining Capacity (lbs/min): 260 | Acres: 260

	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	6.49	2.7	10.61	3.50	12.95	5.40	7.59	3.19
Maturation Days	3.98	2.2	7.12	2.80	9.01	4.12	5.02	2.97
Bad Days	.05	.26	.40	.96	.80	2.78	.14	.59
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	184	21	207	20	293	54	146	36
Bu. Harvested Dry	780	1518	5444	1474	5332	1469	520	1230
Bu. Harvested Moist	4687	1637					4972	1593
Cost of Drying	650	327					701	298
Cost of Chemical	345	173					372	158

* Standard Deviation

District: Lethbridge — Combining Capacity (lbs/min): 95 — Acres: 510

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	16.16	5.98	22.96	9.64	25.66	12.19	17.05	6.38
Maturation Days	4.11	1.64	7.37	2.75	9.25	3.78	5.55	2.85
Bad Days	.18	.72	1.95	3.29	3.38	5.98	.189	.69
% Completion	100		100		99		100	
Bushels Left	-		-		361 in 1 year		-	
Grain Loss	343	13	361	9	444	36	249	19
Bu. Harvested Dry	6416	3329	10726	2884	10106	2723	5547	3135
Bu. Harvested Moist	4326	2709	-		-		4864	2589
Cost of Drying	472	350					550	356
Cost of Chemical	250	186					291	189

* Standard Deviation

District: Lethbridge	Combine Swath Moist		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
Combine Capacity (lbs/min): 135 — Acres: 510	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	12.48	4.8	18.03	6.94	20.28	7.88	13.37	5.01
Maturation Days	4.28	2.01	7.25	2.51	9.34	3.85	5.25	2.70
Bad Days	.06	.31	1.27	2.38	1.76	3.10	.34	1.1
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	347	16	369	10	470	43	253	21
Bu. Harvested Dry	5133	3575	10717	2880	10268	2780	3969	3285
Bu. Harvested Moist	5606	2865	-		-		6601	3166
Cost of Drying	639	416					794	467
Cost of Chemical	339	221					421	247

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 155 | Acres: 510

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	11.54	4.6	16.83	6.71	19.26	8.24	12.69	5.36
Maturation Days	4.12	1.89	7.18	2.58	9.24	4.25	5.20	2.76
Bad Days	.11	.57	1.13	2.00	1.56	3.08	.40	1.12
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	349	18	372	19	475	44	258	27
Bu. Harvested Dry	4829	3584	10715	3889	10298	2770	3917	3438
Bu. Harvested Moist	5909	3015	-		-		6679	3007
Cost of Drying	698	452					810	465
Cost of Chemical	370	240					429	247

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 195 | Acres: 510

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	9.70	3.91	14.62	5.11	16.89	6.64	11.05	4.46
Maturation Days	4.01	2.09	7.39	2.80	9.31	3.78	5.35	3.00
Bad Days	.12	.64	.68	1.68	1.12	2.71	.24	.64
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	346	19	379	17	490	44	263	31
Bu. Harvested Dry	3629	3694	10708	2886	10376	2814	3259	3802
Bu. Harvested Moist	7111	2819	-		-		7401	3246
Cost of Drying	899	463					959	523
Cost of Chemical	477	245					509	278

* Standard Deviation

District: Lethbridge — Combine Capacity (lbs/min): 240 — Acres: 510

	Combine Swath Moist.		Combine Swath Dry		Straight Combine Dry		Straight Combine Moist	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Days	8.28	2.93	12.71	3.97	14.78	4.95	9.39	3.29
Maturation Days	3.92	1.90	6.78	2.32	8.81	3.69	5.05	2.55
Bad Days	.07	.35	.69	1.52	.77	1.85	.04	.24
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	348	25	380	17	506	48	268	39
Bu. Harvested Dry	2889	3372	10707	2887	10417	2834	2558	3126
Bu. Harvested Moist	7580	2961	-		-		8149	2967
Cost of Drying	1005	484					1083	519
Cost of Chemical	533	257					575	275

* Standard Deviation

District: Lethbridge — Combine Capacity (lbs/min): 260 — Acres: 510

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	8.17	3.38	12.48	4.14	14.39	5.32	9.28	3.9
Maturation Days	4.20	2.48	7.18	2.84	8.98	4.06	5.17	3.12
Bad Days	.04	.31	.41	.90	.57	1.21	.20	.86
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	354	27	392	33	519	78	268	38
Bu. Harvested Dry	2602	3247	10695	2897	10423	2855	2130	2949
Bu. Harvested Moist	8130	2892	-		-		8595	2991
Cost of Drying	1040	518					1166	531
Cost of Chemical	552	275					619	282

* Standard Deviation

District: Lethbridge　　Combine Capacity (lbs/min): 95　　Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	22.84	10.41	33.18	18.06	35.32	18.38	22.22	9.40
Maturation Days	3.92	1.82	7.00	2.56	9.06	3.86	4.92	2.41
Bad Days	.10	.41	4.98	7.04	6.87	9.26	.33	1.21
% Completion	100		96		95		100	
Bushels Left	-		15640 in 4 yrs.		22976 in 5 years		-	
Grain Loss	540	15	559	20	655	64	382	28
Bu. Harvested Dry	11496	3983	16675	4416	15175	4054	9223	3707
Bu. Harvested Moist	5355	2663	-		-		6705	3263
Cost of Drying	545	307					724	417
Cost of Chemical	288	163					383	221

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 135 | Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	17.98	8.49	25.32	12.96	28.26	15.21	18.42	8.31
Maturation Days	4.33	3.06	7.21	3.45	9.51	4.96	5.45	3.85
Bad Days	.05	.22	2.56	3.88	4.0	6.72	.22	.85
% Completion	100		99		99		100	
Bushels Left	-		572 in 1 yr.		2279 in 1 year		-	
Grain Loss	542	18	570	14	688	42	395	32
Bu. Harvested Dry	10616	4592	16815	4512	15706	4160	8532	4304
Bu. Harvested Moist	6232	3647	-		-		7695	3867
Cost of Drying	657	475					837	537
Cost of Chemical	348	252					444	284

* Standard Deviation

District: Lethbridge — Combine Capacity (lbs/min): 155 — Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	14.91	6.18	22.38	10.89	24.76	13.40	16.03	6.41
Maturation Days	3.85	1.88	7.20	2.80	9.31	3.82	5.17	2.96
Bad Days	.16	.58	2.28	4.53	3.18	6.30	.29	.86
% Completion	100		100		99		100	
Bushels Left	-		-		10244 in 1 year		-	
Grain Loss	540	21	577	24	701	52	399	32
Bu. Harvested Dry	8957	5200	16814	4528	15809	4176	7611	4896
Bu. Harvested Moist	7893	4304	-		-		8770	4512
Cost of Drying	881	551					1014	648
Cost of Chemical	467	292					538	344

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 195 | Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	13.01	5.11	19.02	7.26	21.23	9.12	14.09	5.4
Maturation Days	4.04	2.16	7.07	2.64	8.93	3.93	5.20	3.06
Bad Days	.07	.38	1.49	2.45	2.19	4.05	.15	.54
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	545	21	581	20	723	46	407	.36
Bu. Harvested Dry	8734	5253	16811	4512	16046	4304	7540	5376
Bu. Harvested Moist	8112	4006	-		-		8967	4496
Cost of Drying	944	558					1067	642
Cost of Chemical	501	296					566	340

* Standard Deviation

District: Lethbridge | Combine Capacity (lbs/min): 240 | Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.97	3.88	16.32	5.61	19.08	7.69	11.96	3.86
Maturation Days	4.05	1.85	7.14	2.44	9.24	4.27	5.08	2.42
Bad Days	.04	.20	.98	1.90	1.72	3.5	.21	.54
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	546	24	589	28	745	70	408	42
Bu. Harvested Dry	7231	5504	16802	4528	16175	4384	5907	5360
Bu. Harvested Moist	9614	4832	-		-		10738	5296
Cost of Drying	1121	639					1357	892
Cost of Chemical	595	339					720	474

* Standard Deviation

District: Lethbridge Combine Capacity (lbs/min): 260 Acres: 800

	Combine Swath Moist Mean	Combine Swath Moist S.D.*	Combine Swath Dry Mean	Combine Swath Dry S.D.	Straight Combine Dry Mean	Straight Combine Dry S.D.	Straight Combine Moist Mean	Straight Combine Moist S.D.
Total Days	10.79	4.51	15.61	5.86	18.19	7.89	12.09	4.6
Maturation Days	4.50	2.55	7.45	2.89	9.64	4.30	5.72	3.09
Bad Days	.05	.41	.69	1.58	1.17	2.63	.23	.83
% Completion	100		100		100		100	
Bushels Left	-		-		-		-	
Grain Loss	547	29	591	24	759	58	408	42
Bu. Harvested Dry	6849	5776	16800	4512	16219	4352	5450	5408
Bu. Harvested Moist	9995	4784	-		-		11231	5168
Cost of Drying	1223	703					1373	756
Cost of Chemical	649	373					729	401

* Standard Deviation